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LIGATION AND DIVISION OF THE ABDOMINAL AORTA FOR METALLIC EMBOLUS FROM THE HEART

POSTOPERATIVE OBSERVATIONS OF THE CIRCULATION IN THE EXTREMITIES

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SINCE THE ORIGINAL REPORT by Sir Astley Cooper, in 1817, of ligation of the abdominal aorta for aneurysm, the method and results have interested many surgeons. The first successful case of ligation of the terminal aorta was reported by Brooks,[10] in 1926. The subject was reviewed by Bigger,[1] Elkin,[2] and Matas,[3] in 1940, with discussion of the problems involved and of the complications which frequently follow. Gangrene, erosion of the vessel, hemorrhage, and recurrence of the aneurysm are common.

These authors collected a series of 30 cases of ligature of the abdominal aorta for aneurysm of the aorta or of the common iliac vessels. Elkin[2] included four instances of ligation of the aorta for trauma or tumors. Morton and Scott[4] reported an additional case of ligation for aneurysm of the bifurcation of the aorta in 1944, with the patient living for seven months. Another case was reported by Monohan[5] with survival for three months. Both of these cases died of hemorrhage resulting from erosion into the small intestine. Ormond, Harkins, and Smith[6] reported a case of ligation of the aorta for a ruptured aneurysm, with the patient surviving for one day. Nario[7] reported a case of partial ligation of the aorta for aneurysm of the aorta and common iliacs, with survival. Delannoy[8] excised the bifurcation of the aorta for thrombosis with recovery in 1945. Frieh and Morel[9] successfully excised the bifurcation of the aorta for thrombosis, with postoperative improvement in the circulation of the extremities; a bilateral lumbar sympathectomy was performed.

Of the 36 cases appearing in the literature only 12 have been to any degree successful.

The following case is reported since it is the only one in which excision of the bifurcation of the aorta was necessitated by erosion of a portion of the

wall of the aorta by a foreign body within its lumen. The patient made an uneventful clinical recovery.

CASE REPORT

This 22-year-old male soldier was treated at overseas hospitals for a stricture of the urethra; physical examinations were normal except for this condition.

He sustained a penetrating wound of the left arm and chest, May 26, 1945, when he was shot with a .45-caliber pistol, and was admitted to an hospital shortly after the injury. At this time he was breathing quietly and was not in shock. A wound of

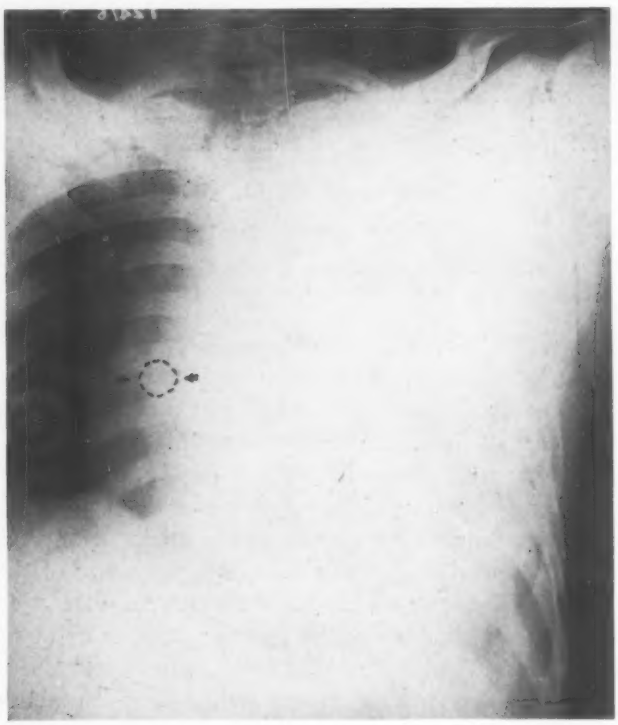

FIG. 1.—Retouched roentgenogram of chest shortly after injury showing an hydropneumothorax, displacement of the mediastinum to the right and the foreign body within the heart.

entrance was present on the lateral aspect of the left arm with a wound of exit from the arm on the medial aspect near the axilla; the bullet then entered the chest between the 4th and 5th ribs. Roentgenograms showed the foreign body in the heart and a left hemopneumothorax (Fig. 1).

After plasma had been administered the fracture of the humerus was treated by débridement and a "hanging cast"; the wound of the chest was débrided and sutured, with drainage. Fourteen hours later his blood pressure in both arms was 115/70, pulse 100, and there was no dyspnea or cyanosis.

On the following day his condition continued unchanged except that a loud "swishing" murmur was heard over the sternum; the murmur had not been present the preceding day. At this time it was noted that the pulses in the feet were equal. Thoracentesis

was performed on four occasions, and by June 13, 1945, the mediastinum had returned to its normal position (Fig. 2); the murmur over the precordium diminished.

On June 21, 1945, he suddenly complained of pain, coldness, and numbness of the right foot. On examination, there was no palpable dorsalis pedis pulsation on the right although the one on the left was good. The following day the femoral pulse on the right also disappeared; the pulsations of the arteries of the left lower extremity diminished. On June 24, 1945, a roentgenogram was taken which showed the .45-caliber bullet at the bifurcation of the aorta. At this time the left dorsalis pedis pulse had disappeared, with the femoral pulsation definitely diminished.

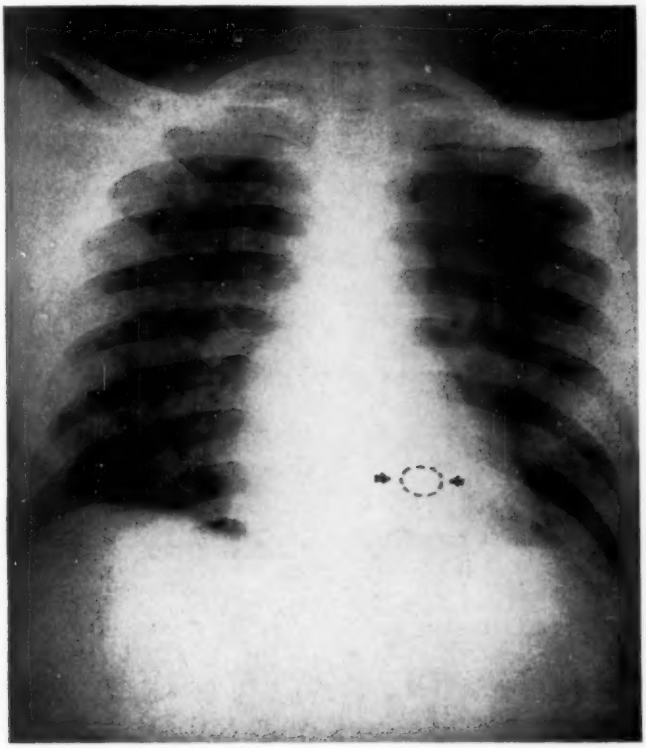

FIG. 2.—Retouched roentgenogram following disappearance of the hydropneumothorax, with the foreign body in the heart.

During the following two weeks the murmur over the precordium diminished in intensity, and the palpable pulsations in the lower extremities varied, although faintly palpable on either side. The condition of the feet continued "good, without edema."

On July 12, 1945, a left paravertebral lumbar sympathetic block was performed.

An attack of severe, sharp, stabbing precordial pain radiating to the abdomen and right hip region occurred on July 22, 1945. A very loud systolic murmur was heard over the entire chest; the abdomen was rigid, with tenderness most marked in the right lower quadrant. Pulsations were felt in both dorsalis pedis arteries. It was believed that in view of the changes in pulsations in the extremities that the pain had been produced by shifting of the bullet in the aorta or by a dissecting aneurysm of the aorta. It was also feared that blood had leaked into the peritoneal cavity, but the pain and tenderness disappeared within two days. During the following nine days the pulse in the right lower

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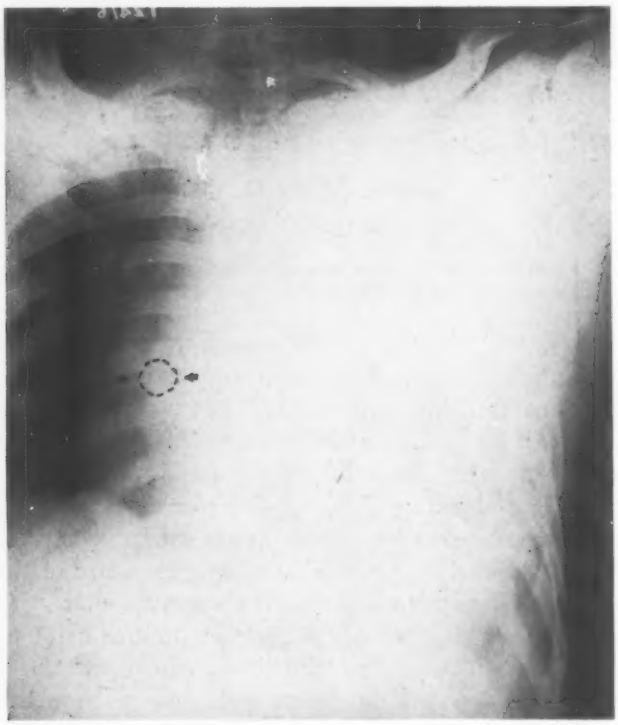

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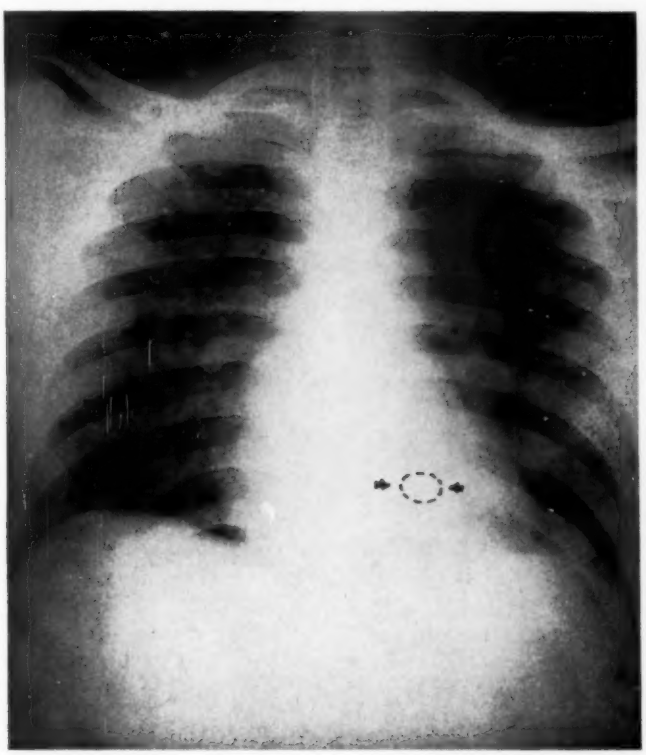

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extremity varied in amplitude, with those on the left absent. On August 1, 1945, the episode of chest and abdominal pain recurred, with all symptoms and signs subsiding on the following day. On August 9, 1945, he was transferred to the United States, and admitted to Ashford General Hospital, November 13, 1945, complaining of weakness and fatigability of both legs and of coldness of the right foot.

Physical examination on admission revealed all wounds to be completely healed. A loud systolic murmur was present over the precordium, maximum at the level of the right third intercostal space. A loud diastolic murmur was also present, but with a short interval between, giving the total murmur an almost continuous quality. A thrill was

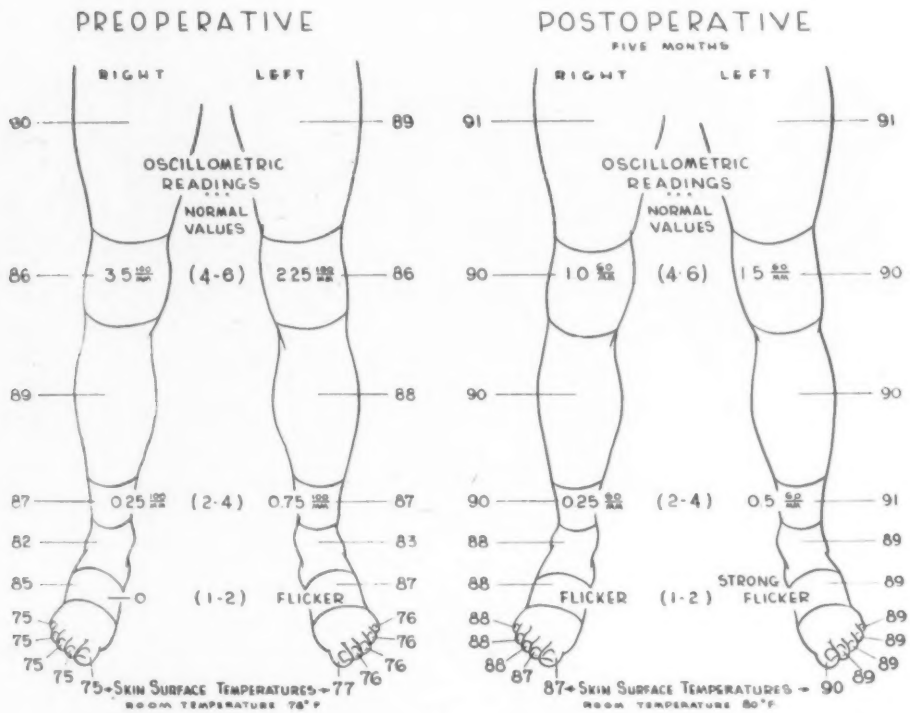

FIG. 3.—Preoperative and postoperative skin surface temperatures and oscillometry.

palpable in the same region. The bruit was transmitted to the left upper chest, lower neck, and intrascapular region. It could also be heard along the aorta to the level of the umbilicus. Blood pressure in the upper extremities was 130/60 right, 130/90 left.

Vascular Evaluation: The right foot became pallid on elevation. There were no trophic changes in the extremities; no sweating, scleroderma or edema. The left dorsalis pedis pulse was faint, the right absent. Both posterior tibial pulses were absent. The popliteal pulsations were moderate. The upper extremities were normal. Oscillometry and skin surface temperatures were as shown in Figure 3.

Roentgenographic and fluoroscopic examination of the chest showed no evidence of pathology in the thoracic aorta. Moderate enlargement of the right auricle was present: C. T. ration was 15.2/29.6. Examination by means of Bucky and planeographic films failed to demonstrate any abnormality of the thoracic aorta. Examination of the lumbar

region revealed a large metallic foreign body lying at the third lumbar interspace slightly to the left of the midline (Fig. 4). The mass pulsated with a downward motion in time with the pulsations of the aorta.

Electrocardiogram revealed a normal sinus rhythm, PR interval of .20 Sec, QRS complexes .07 Sec, T_2 notched and T_3 diphasic.

White blood count was 6,750 with hemoglobin of 15 Gm.; urinalysis was normal. Frei test was positive, Kahn negative.

The soldier's hospital course was uneventful until December 8, 1945, when, while sitting in church, he had another episode of substernal pain followed by radiation to the left chest, into the abdomen and into both inguinal regions. Shortly thereafter he became nauseated and vomited. Physical examination was essentially unchanged except for a rigid abdomen. All signs and symptoms subsided within three days.

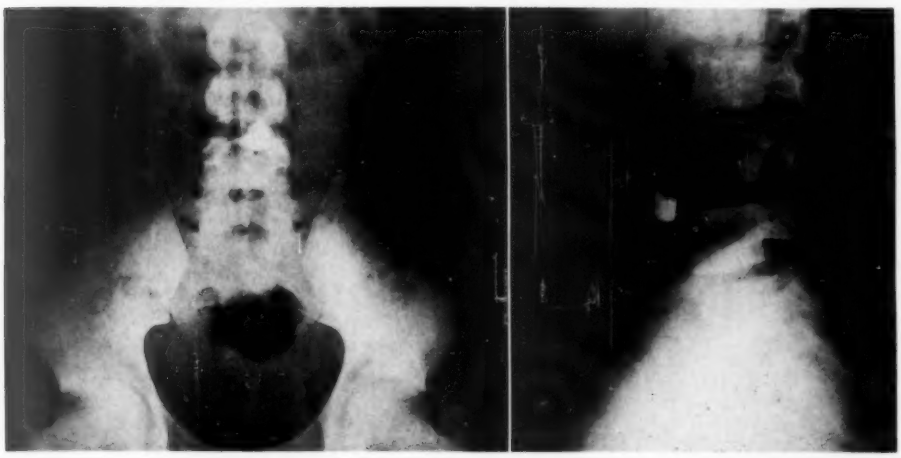

FIG. 4.—Roentgenograms of the abdomen with the foreign body at the bifurcation of the aorta.

Since the patient complained of recurrent attacks of chest and abdominal pain, it was feared that the abdominal aorta was being eroded by the irregular foreign body and that eventual rupture of the vessel would occur. This belief was partially substantiated by fluoroscopic examination which demonstrated motion of the foreign body and by the evidence of peripheral vasospasm in the lower extremities from irritation of the aortic wall. An operation was planned in which an attempt would be made to remove the foreign body from the aorta.

Operation.—December 28, 1945: Under gas, oxygen, and ether anesthesia, a left paramedian incision was made. The bifurcation of the aorta was exposed transperitoneally, with vertical incision of the posterior peritoneum just to the left of the midline. The aorta was approximately one-half of its normal diameter and was tightly constricted about the foreign body. A fusiform dilatation was present in this region, with partial erosion of the wall. The common iliac vessels did not pulsate. The aorta was mobilized below the inferior mesenteric artery and a small soft rubber tube placed beneath it. The common iliac vessels were similarly mobilized with rubber tubing placed around them. In view of the erosion of the vessel wall it was believed that removal of the foreign body with restoration of continuity of the vessel was not possible. Bulldog clamps were placed on the common iliac vessels and the skin surface temperatures of the feet observed. After a period of observation for 15 minutes, during which the skin surface temperatures

did not change (Fig. 5), the iliac vessels were doubly ligated with double-zero braided silk, transfixed, and divided.

The vessels were found to be obstructed at the bifurcation by partially organized thrombus. The bullet was removed from the aorta (Fig. 7). The lumen at the aortic bifurcation was filled with a partially organized thrombus which surrounded the foreign body and was firmly adherent to the initial lining. Bleeding from the middle sacral artery was encountered when the thrombus was removed and was controlled by ligation of the vessel. The aorta was ligated immediately below the origin of the inferior mesenteric artery. This occlusion was accomplished by two ligatures of double-zero braided

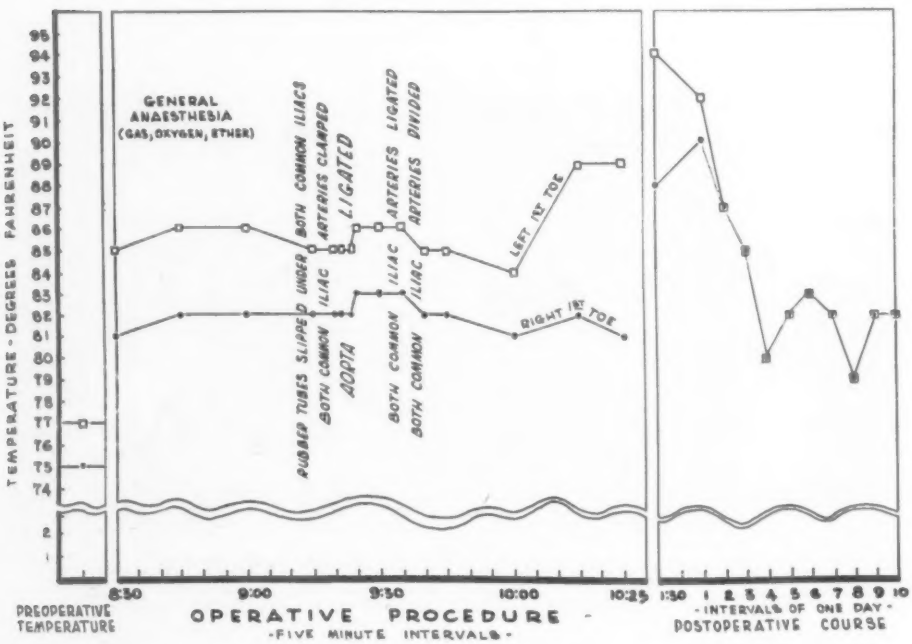

FIG. 5.—Skin-surface temperatures of the first toes during the operative procedure and for the ten days following operation.

silk and a transfixion suture. A portion of the eroded aorta was removed (Fig. 6). The posterior and anterior peritoneal incisions were closed with a continuous catgut suture. The abdominal wound was closed in layers with fine silk sutures. Skin surface temperatures of the first toes were recorded every five minutes during the operative procedure.

Postoperatively, the skin surface temperature of the feet were observed as charted (Fig. 5). Sympathectomy or sympathetic blocks were not considered necessary. Anticoagulants or drugs for vasodilatation were not used. Skin resistance determinations were normal postoperatively confirming the presence of normal sympathetic innervation of the lower extremities.

During the first three postoperative days oral temperatures varied from 99° to 100° F. During this period the skin surface temperatures of the first toes remained abnormally high. These findings demonstrated a normal vasomotor response in the extremities to elevation of general body temperature. These temperatures returned to normal levels on the 4th postoperative day, when the fever subsided. Temperature recordings were made daily for ten days after operation.

The response of the skin surface temperatures of the first toes to changes in environmental temperature was determined on the 65th postoperative day. The patient was exposed, with all clothing removed, in a constantly controlled temperature room for 30 minutes before the test was begun. The temperature of the room was maintained at 76° F. for one hour as control and readings were recorded. The temperature was then lowered to 64° F. (cold room) for one hour; temperatures were recorded at ten-minute intervals. The room was then heated to 85° F. (warm room) for one hour, and responses in skin temperature of the first toes were recorded as shown in Figure 8. Change from the 76° F. level of the room to 64° F. was completely effected within ten minutes.

FIG. 6.—Artist's conception of the operative procedure. The foreign body had been removed and a portion of the injured aorta excised. An additional segment of the damaged aorta is being excised.

Similarly the change from 64° F. to 85° F. was attained within ten minutes. The temperature levels of the normal, cold, and warm environments were constant. The humidity was controlled at low saturation levels.

Subsequent Course.—It can be seen from the variations in skin surface temperatures that the normal vasomotor mechanism has remained sufficiently labile to insure the patient a tolerance for environmental change in temperature. Both lower extremities responded similarly to the changes.

Five months after operation the oscillometry and skin surface temperatures of the

extremities were again determined (Fig. 3). It can be seen that at the time of the initial examination the occlusion of the aorta was not complete; the complete obliteration of its lumen probably occurred at the time of the severe abdominal pain 20 days prior

FIG. 7.—The foreign body removed at operation. Multiple irregular projections are present.

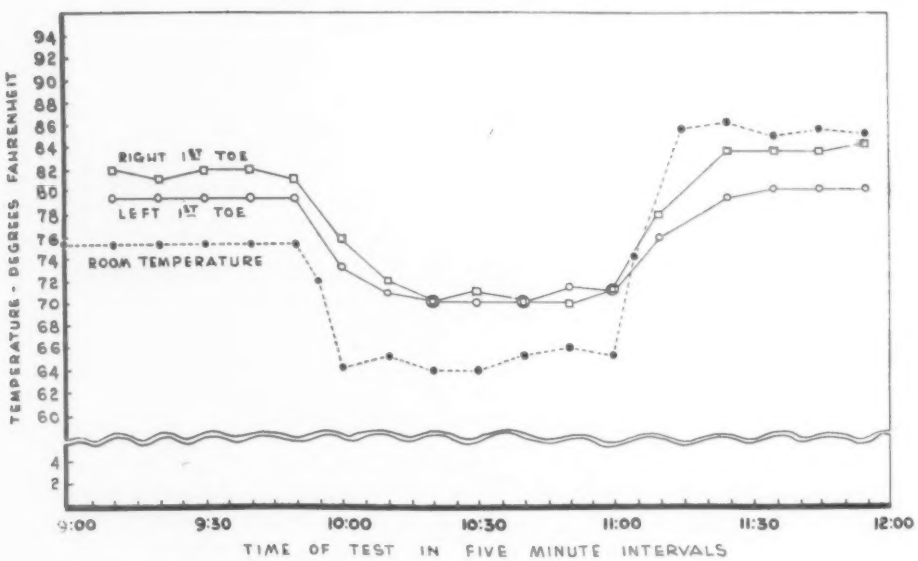

FIG. 8.—Skin surface temperature studies of both first toes in constantly controlled room at normal, cold, and warm levels 65 days following ligation and division of descending aorta and both common iliac arteries.

to operation. At the end of five months the formation of adequate collateral circulation is shown by the greater skin surface temperatures in both lower extremities at levels well above the normal, as compared with subnormal readings preoperatively. This is particularly significant since the oscillometry postoperatively is at levels indicative of major

arterial obstruction. The decrease in pallor of the right foot on elevation and continued absence of pallor in the left foot on elevation further confirms the presence of improved collateral circulation. Since the oscillometry had originally been less on the left it can be assumed that obliteration of the common iliac of that side occurred first, and that a greater period had elapsed for the establishment of collateral channels.

The patient believed that he had been benefited by operation. He stated that he was able to walk greater distances without tiring and that he had had no recurrence of the abdominal or chest pain.

The conditions present in this case gave an ideal sequence leading to ligation of the aorta. The patient was young with the vascular elasticity of youth. Occlusion of the aorta was not sudden but progressed over a period of several weeks, with variations in the completeness of obstruction to blood flow. Finally, at the time of operation, the vessel had become completely occluded with an adequate collateral circulation established. Operation in this instance, actually, immediately improved the circulation in the legs as manifested by the prompt rise in skin surface temperatures of the toes (Fig. 5).

The immediate rise in skin surface temperatures of the toes, after the aorta had been ligated with the subsequent greater postoperative elevation, is probably accounted for on the basis of relief from the reflex vasoconstriction of the distal arterial bed (Leriche and Werquin[13]) produced by the constant trauma and irritation of the arterial wall and periarterial sympathetic plexus by the irregular foreign body.

It has been stressed by Brooks,[10] that absence of pulsations in the femoral arteries is indicative of adequate collateral channels for blood supply to the lower extremities in the presence of an aneurysm of the abdominal aorta. Brooks,[10, 11] Blalock and Johnson[10, 11, 12] have also shown that such a ligation of the abdominal aorta places no additional strain upon the heart by increased peripheral resistance, which one would suppose to follow obstruction of that vessel. It was shown by them that the cardiac output is decreased and that there is little change in the blood pressure in the artery proximal to the occlusion.

The collateral circulation probably develops through the anastomoses of the inferior mesenteric with the inferior hemorrhoidal arteries; the inferior epigastric artery with the superior epigastric artery; and, through the two lower lumbar and iliolumbar arteries with the internal iliac arteries. The anastomoses of the lumbar, iliolumbar, and internal iliac arteries were excellently demonstrated by Morton and Scott[4] in a case of ligation of the aorta by injection of a radiopaque liquid latex mass at the time of autopsy seven months after partial ligation of the aorta.

It has been the common practice to use a broad cotton tape, rubber or metallic bands for occlusion of the aorta.[2, 4, 5, 6, 7, 15, 16, 17, 18] It has been stressed by Holman[14] that with ligation of the vessel in continuity the maximum force of each arterial pulsation is concentrated at the site of ligation, whereas, following ligation and division the force of each pulsation is dissipated by expansion and elongation of the thickened, retracted proximal seg-

ment with less strain at the point of ligature. Erosion of the arterial wall with subsequent partial restoration of the lumen of the vessel or rupture[4, 5] frequently follow ligation without division, even though large ligatures are used. In the case reported, occlusion of the vessel was accomplished with double-zero braided silk ligatures followed by complete division of the aorta. It is believed that with ligation and division of the large vessels, ligatures of small size may be used with safety.

SUMMARY AND CONCLUSION

1. Thirty-six cases of partial or complete ligation of the abdominal aorta appear in the literature, with 12 of these cases successful.

2. An instance of ligation and excision of a portion of the abdominal aorta for a metallic embolus from the heart is presented.

3. Postoperatively, the distal vascular bed was relieved of vasospasm produced by the foreign body.

4. The lower extremities reacted normally to changes in environmental temperature after aortic division.

5. Collateral circulation developed rapidly with increase in tolerance for exercise.

6. Sympathectomy or sympathetic blocks were not considered necessary.

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ONE-STAGE RESECTION AND ANASTOMOSIS OF THE COLON

UTILIZING THE FURNISS CLAMP

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THE PENDULUM OF SURGERY of the large intestine has returned to its starting point. Modern writers again advocate colon resection with primary anastomosis and without complementary colostomy. It is our purpose to discuss the reasons for this trend and to present a technic of resection and anastomosis which has produced satisfactory results.

The first reported resection of the colon was performed by Reybard[28] in 1833. He chose end-to-end anastomosis as the most logical means of re-establishing continuity of the intestine. His patient, like the second case reported by Thiersch[30] in 1875, died of peritonitis. It was not until 1881 that a successful case was recorded by Kohler.[16] In 1889, Billroth[3] analyzed 17 cases, with the forbidding mortality of 60 per cent. It is not surprising, therefore, that when von Mickulicz[31] reported 24 operations for resection of the colon by means of the exteriorization method that bears his name, with a mortality of only 16.6 per cent, surgeons hailed this method as a great modern advance in surgery of the colon. Von Mickulicz[31] did not claim originality for this procedure. In one of his early papers he refers to the work of Bloch[4] in 1892. Traditionally, Paul[25] has also been given credit for having independently utilized the operation in 1895. However, it is not generally known that Heinecke[11] wrote of the exteriorization method in his "Vorlagerung und Extraperitoneal Resektion" two years before Bloch.[14]

The multiple-stage exteriorization operation, or one of its modifications, has been the operation of choice for resection of the colon at all levels, excluding the rectum. As experience grew, certain disadvantages became apparent. Multiple operations, with the accompanying multiple operative risks, are necessary. In addition, there is a high incidence of complications, such as wound disruption, wound infection, persistent fistulae, and postoperative herniae. Convalescence and hospitalization are prolonged. The artificial anus, although temporary, is an annoyance. In order to create adequate spur there may be a tendency to save colon and its mesentery and, thereby, to jeopardize the efficacy of the cancer operation. The danger of local implants of carcinoma on the abdominal wall has largely been abolished by the obstructive resection of Rankin.[26] However, this operation requires temporary complete obstruction of the colon.

Proponents of multiple-stage colonic surgery state that the low mortality possible with this operation outweighs its disadvantages; Rankin[26, 27] Lahey,[17] Cheever,[5] in 1931, reported comparable series of cases and showed that in their hands, one-stage resections, with anastomosis and a proximal vent for decompensation, had a lower mortality than the exteriorization

procedures. Harvey,[10] Wilkie,[36] MacFee,[21] Finsterer,[7] Joll,[12] Gibbon and Hodge,[9] and Stone and McLanahan[29] gave similar statistics. According to Gibbon and Hodge, the combined mortality of their cases and those of MacFee,[21] Wilkie,[36] and Stone,[29] representing 246 primary aseptic colonic resections, some with and some without a proximal vent, was 14 per cent. Coin-

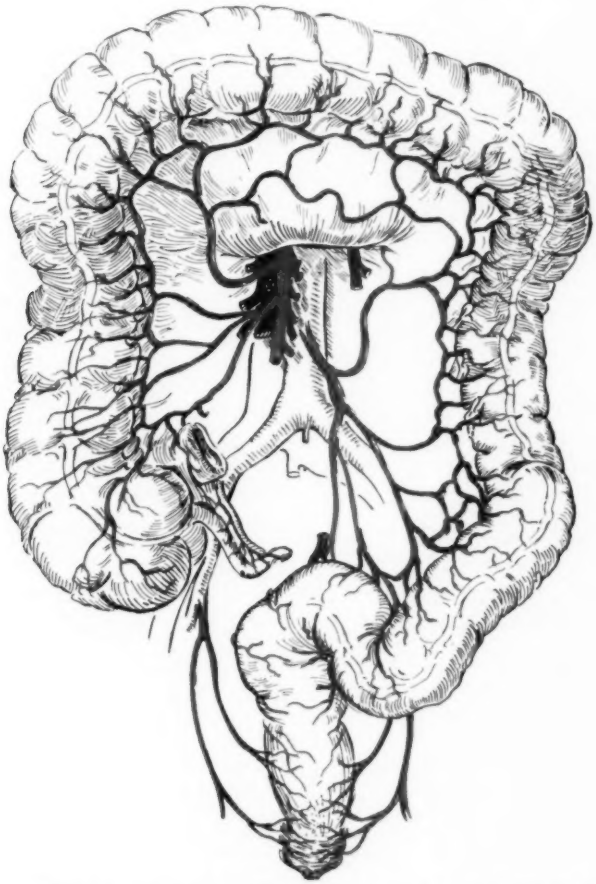

FIG. 1.—Blood Supply of the Colon (after Jones and Shepard).[13] Right colic artery supplies terminal ileum and caecum through ileocolic branch. Ascending colon supplied by secondary right colic branches. Marginal anastomotic branch meets branch from middle colic at hepatic flexure. Middle colic artery supplies hepatic flexure, and transverse colon, gives off long anastomotic marginal artery which together with branch from left colic artery supplies entire transverse colon and a portion of the hepatic flexure. Left colic artery supplies splenic flexure and descending colon. Two or three sigmoidal arteries given off by the inferior mesenteric supply the sigmoid colon. The continuation of the inferior mesenteric is called the superior hemorrhoidal, this supplies the rectosigmoid. The middle and inferior hemorrhoidal come off the hypogastric artery. Note the poor blood supply on the anti-mesenteric border of the intestine and the absence of anti-mesenteric border anastomoses.

cident with the introduction of the Miller-Abbott tube for decompression in resections of the right colon, and the use of intestinal chemotherapeusis, this mortality has been reduced further. White and Amendola[35] report a mortality of 11 per cent, Babcock[1, 2] 9.4 per cent, Meyer, *et al.*[23] 5 per cent, Waugh[34] 4 per cent, and Wangensteen[32, 33] 1.7 per cent.

Most writers agree that a proximal colostomy or ileostomy is not necessary in the patient who is not suffering from obstruction, Harvey,[10] Mayo and Simpson,[22] Stone and McLanahan,[29] Wangensteen,[32, 33] Waugh,[34] Meyer, *et al.*[23] Others, Babcock,[1, 2] and Dixon,[6] continue to recommend a proximal vent. Generally, it is believed that an aseptic anastomosis is desirable, although Meyer[23] has recently reported a series of 20 open anastomoses, with a mortality of only 5 per cent.

TABLE I

Resected Section	Diagnosis	No. of Cases	Complications (Abdominal)	Age Range	Average Age	Range P. O. Days	Average P. O. Days	Mortality
Terminal ileum, cecum, ascending colon, hepatic flexure	Adeno-carcinoma (5) Regional enteritis (7)	12	1. Intestinal obstruction, requiring ileostomy 2. Paralytic ileus, intubated	27 to 57	43	7 to 30	18	0
Transverse colon	Adeno-carcinoma Ulcerative colitis	1	0	25	25	19	19	0
Splenic flexure	Adeno-carcinoma	5	1. Peritonitis abscess, fecal fistula	37 to 66	50	9 to 76	29	0
Descending colon	Adeno-carcinoma	1	0	68	68	13	13	0
Sigmoid	Adeno-carcinoma (5) Chronic colitis (1)	7	0	37 to 76	49	8 to 28	15	One, on 5th P. O. day, pulmonary embolus
Totals		26	11.5%	27 to 76	42	7 to 76	19	3.8%

We are reporting a series of 26 consecutive colonic resections, covering all regions of the colon above the peritoneal reflection, which were done in one stage without a proximal colostomy or ileostomy, and anastomosed aseptically with the Furniss clamp, with a mortality of 3.8 per cent (Table I). The one fatality occurred with the dramatic suddenness of a pulmonary embolus on the fifth day, while the patient, ambulated early, was returning from the lavatory. There were three abdominal complications in this series (Table I). Two patients obstructed postoperatively, one required intestinal intubation and the other an ileostomy. A third patient developed peritonitis, an intraperitoneal abscess and a fecal fistula due to a faulty anastomosis. This patient was hospitalized for 76 days.

The postoperative hospital stay of this group of patients varied from 7 to 76 days, and averaged 19 days.

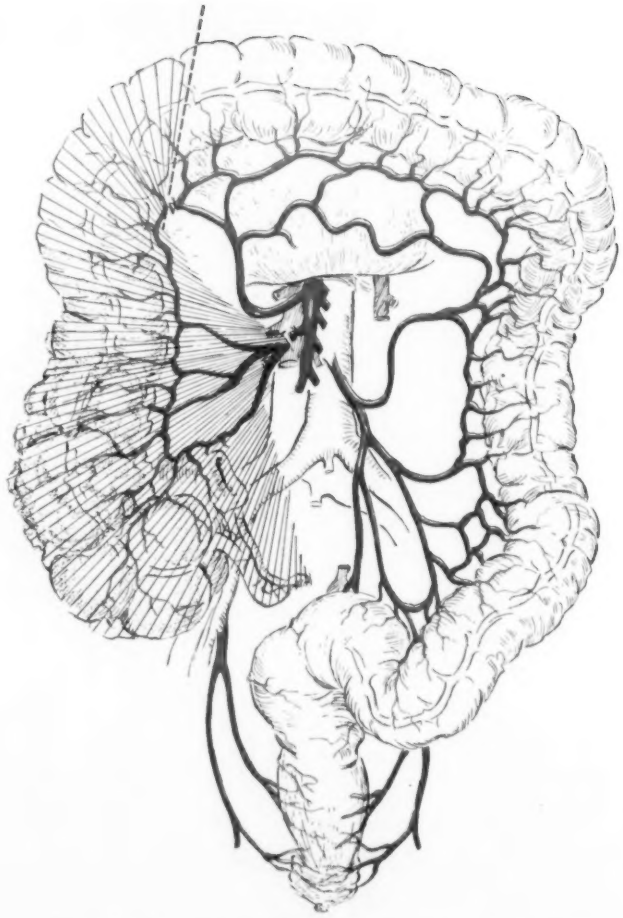

FIG. 2.—Resection of Right Colon. Terminal ileum, caecum, ascending colon and hepatic flexure removed. Right colic artery ligated, middle colic artery preserved. Note section of intestine at 45 degree angle to insure blood supply at anti-mesenteric border.

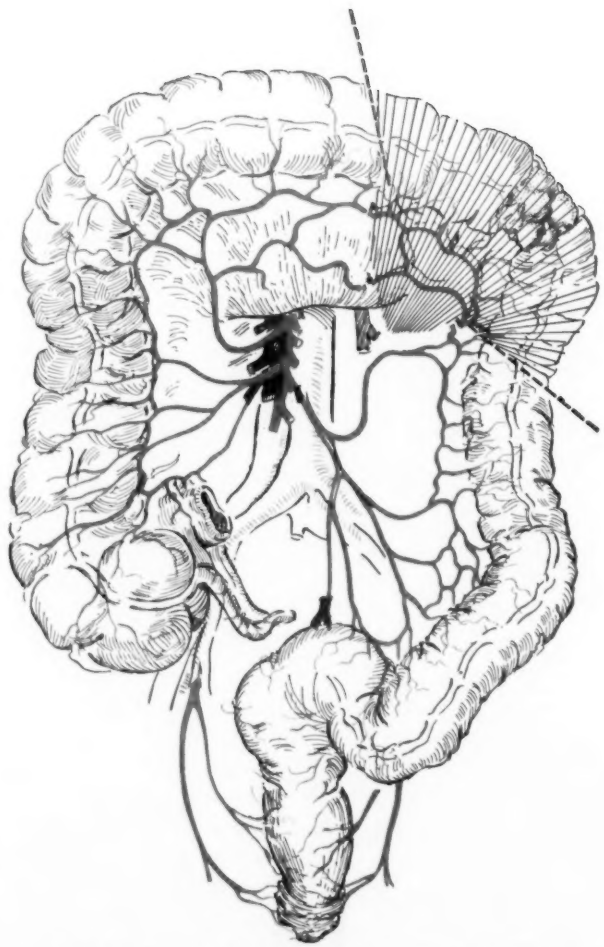

FIG. 3.—Resection of Splenic Flexure. Branches of middle colic and left colic arteries ligated. Main arteries preserved. Note section of intestine at 45 degree angle to insure blood supply at anti-mesenteric border.

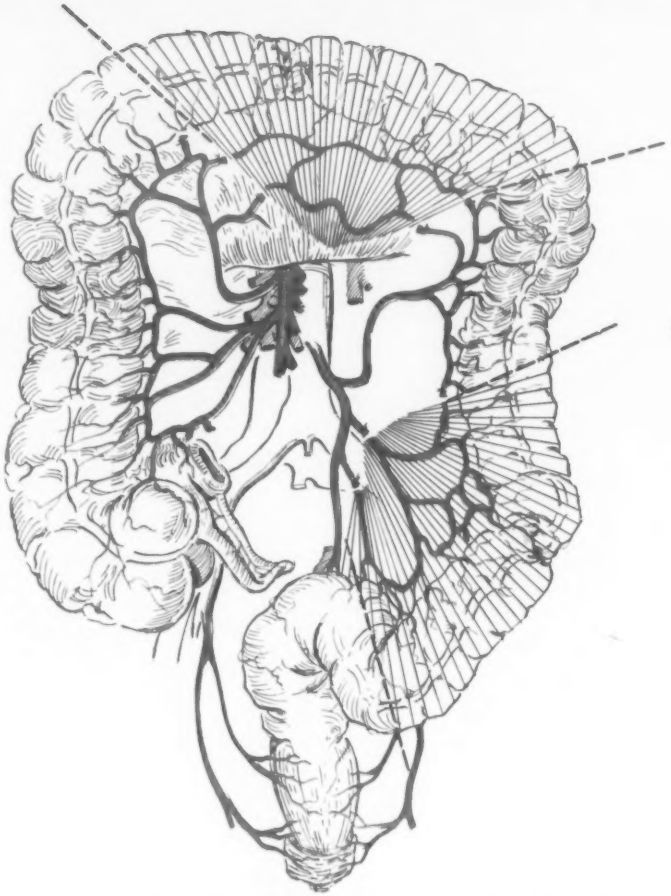

FIG. 4.—Resection of Transverse Colon. Left colic and middle colic arteries preserved.

Resection of Sigmoid Colon. Sigmoidal branches of inferior mesenteric artery ligated. Superior hemorrhoidal artery and marginal artery of left colic preserved. Note section of intestine at 45 degree angle.

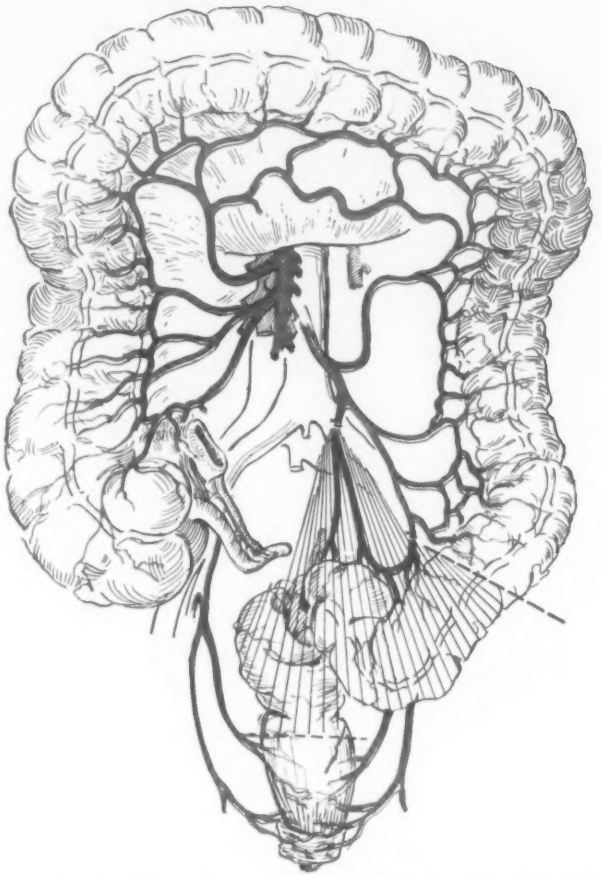

FIG. 5.—Resection of Recto-Sigmoid. Upper sigmoidal artery preserved. Superior hemorrhoidal artery ligated. Middle and inferior hemorrhoidal arteries preserved.

Careful selection, adequate pre- and postoperative treatment, and attention to details are prerequisites for success in this field of surgery. Only nonobstructed patients are selected for this procedure. The obstructed patient is not a candidate for one-stage resection and anastomosis without a proximal vent. He is first treated for intestinal obstruction by appropriate medical and surgical decompression.

Five to seven days are allowed for preoperative preparation. During this period, aberrations are corrected in fluid and electrolyte balance, anemia, hypoproteinemia, and vitamin deficiencies. In addition, vigorous attempts are made

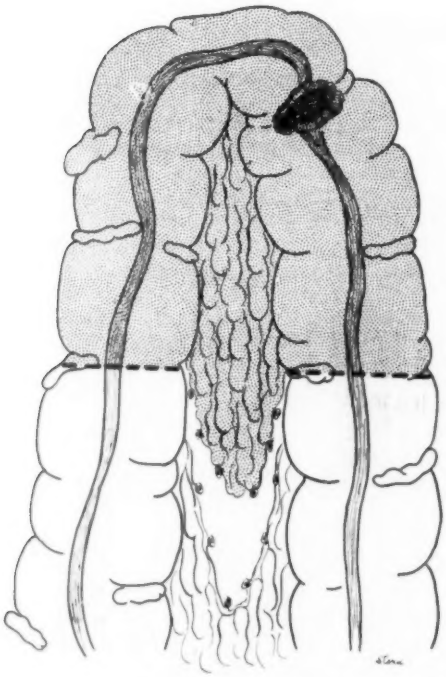

FIG. 6.—Colon prepared for application of clamp.

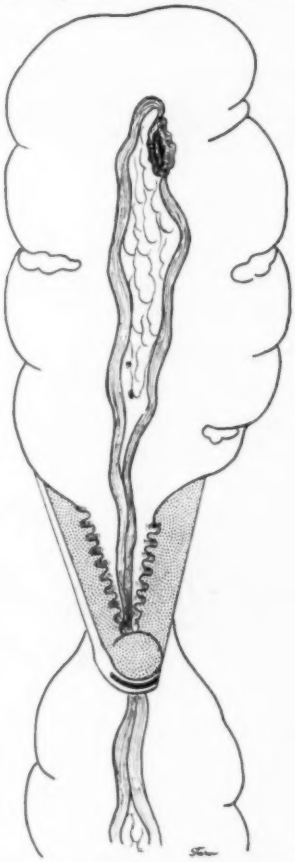

FIG. 7.—Limbs of colon rotated medially. Clamp applied at 45 degree angle to anti-mesenteric border.

to replenish the stores of tissue proteins. Our patients receive per day, 2,000 cc. of amigen, 500 mg. of ascorbic acid, and 200 mg. of vitamin B-complex parenterally. Anemia is corrected by transfusion of whole blood. The patient is placed upon a high protein, low residue, diet. Purging with magnesium sulphate is carried out for the first two days of preoperative preparation. Throughout the period the patient receives 12 Gm. of succinylsulfathiazole

per day. At operation, the colon will be found collapsed and free from fecal material.

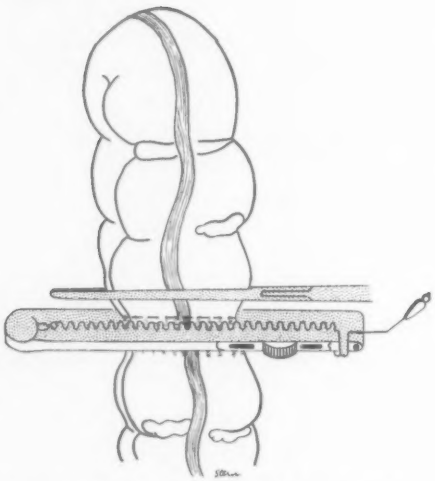

FIG. 8.—Furniss clamp applied. Specimen ready for excision.

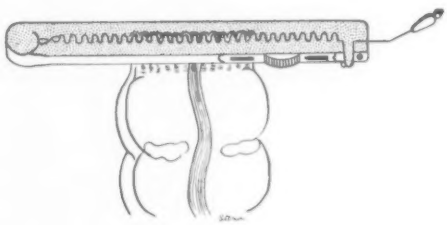

FIG. 9.—Specimen removed. Limbs of intestine held firmly by clamp and pin.

According to Kerr,[14, 15] about 250 methods of intestinal anastomoses have been reported. Of these methods, about 45 are aseptic or nearly aseptic. We have chosen to perform aseptic anastomosis of the colon because we feel that in spite of chemotherapeutic antisepsis of the colon, modern surgical thought dictates that contamination, no matter how innocuous, be kept to a minimum. The method of anastomosis which we have found useful was first described by Furniss[8] in 1934, and utilizes a clamp that retains the soundness of the

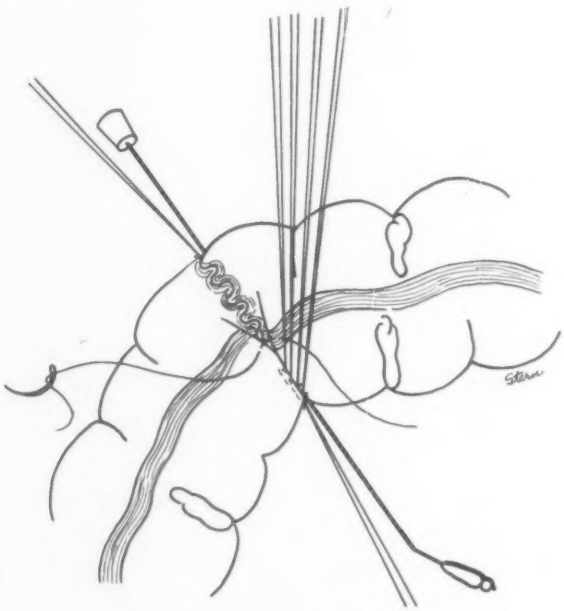

FIG. 10.—Stay sutures placed before removal of clamp. Limbs to be anastomosed, held by pin. First anterior row of interrupted Lembert sutures placed.

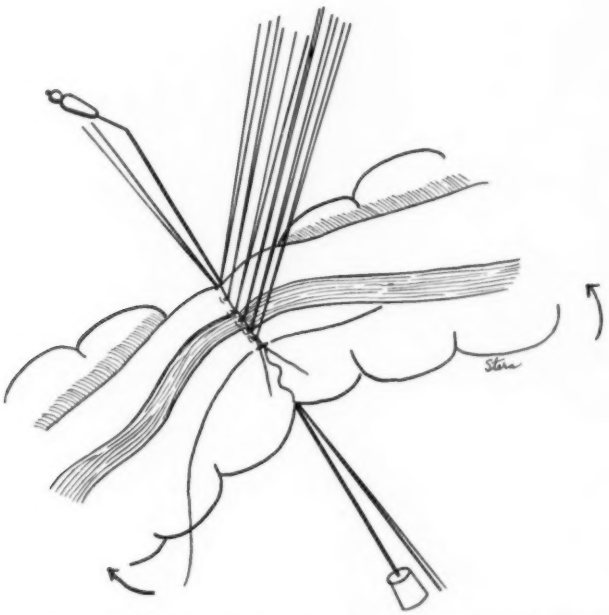

FIG. 11.—First anterior row complete. Colon rotated by turning pin clockwise or counter-clockwise. First posterior row of Lembert sutures placed.

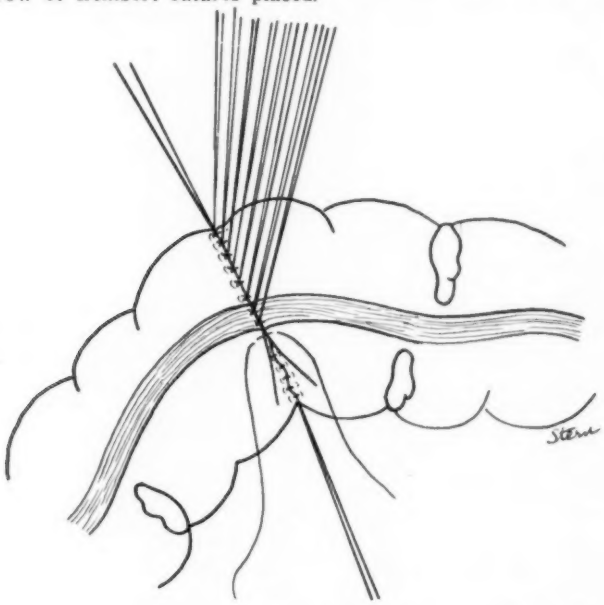

FIG. 12.—Pin removed. Second posterior row of Lembert sutures placed.

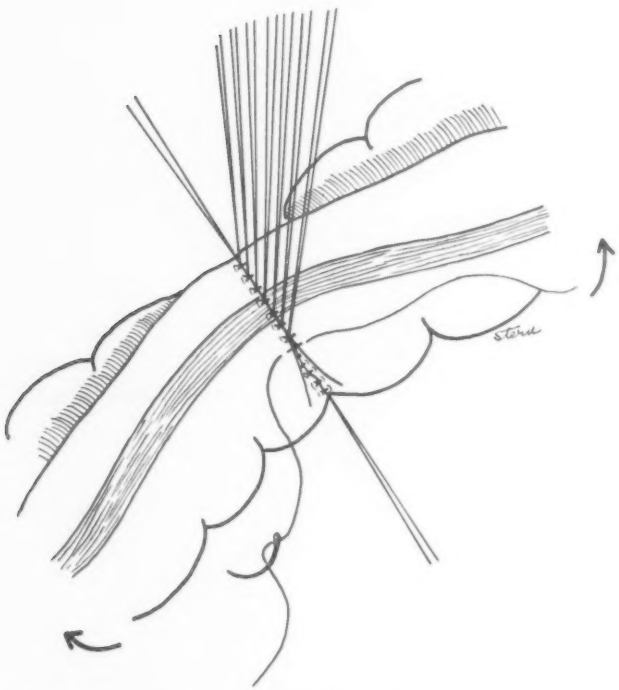

FIG. 13.—Colon, rotated back to normal position. Second anterior row of Lembert sutures placed.

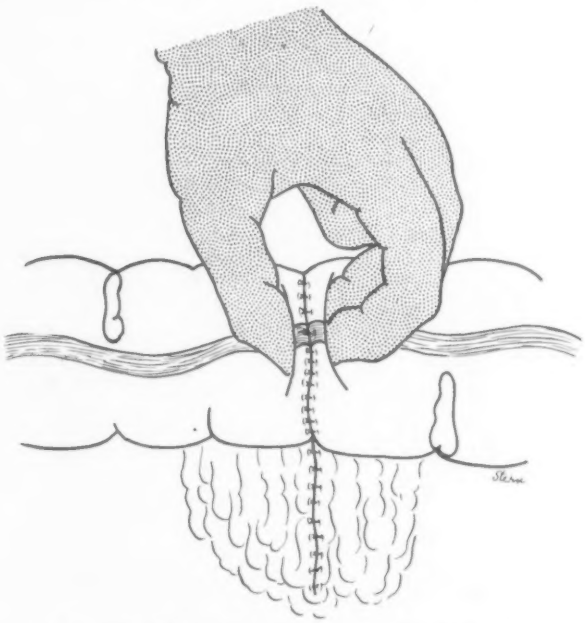

FIG. 14.—Diaphragm opened by manipulation and patency of anastomosis tested. Defect of mesentery repaired by interrupted sutures.

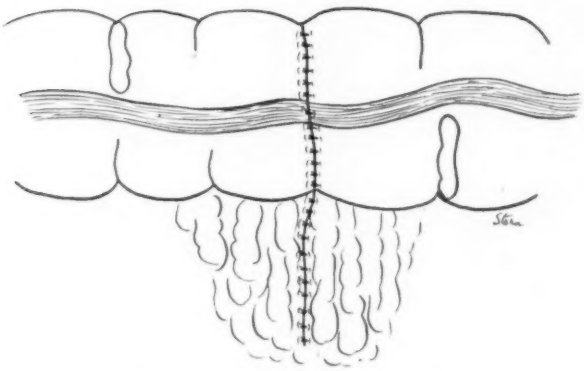

FIG. 15.—Complete anastomosis.

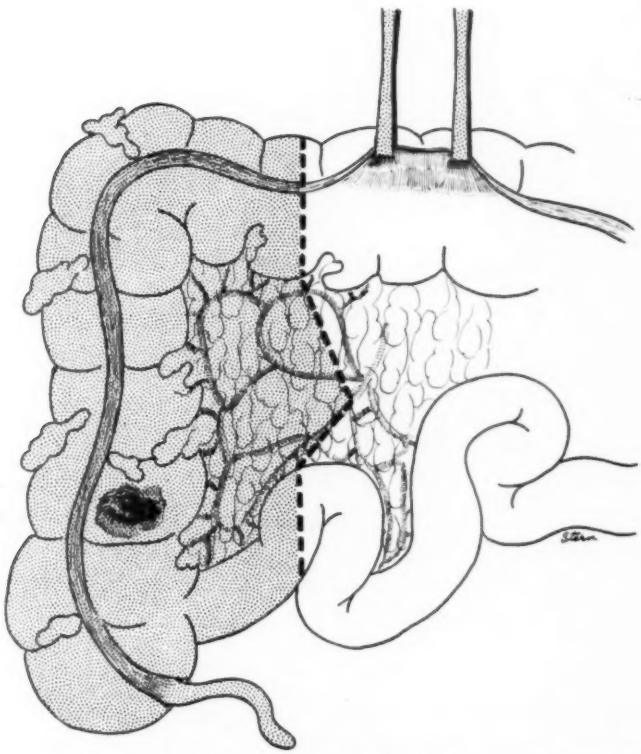

FIG. 16.—Illustrated area to be excised. Allis clamps placed on taenia, raising a tent of all layers of the transverse colon.

Parker-Kerr[24] basting stitch but simplifies the technical steps of the procedure. Furniss[8] advised the use of two clamps for anastomosis of the colon. He felt that because of the thickness of the wall, a single clamp would not give adequate pinning. The McClure[20] modification of the Furniss clamp corrects this deficiency of the original instrument, and only one clamp has been found necessary.

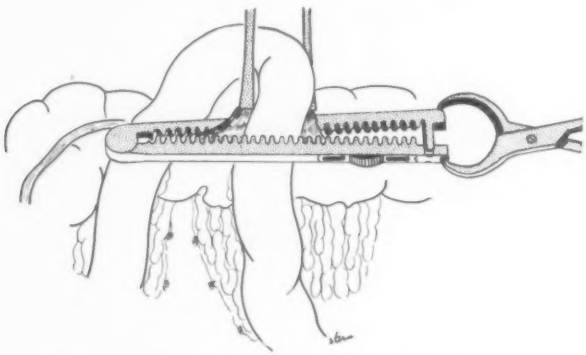

FIG. 17.—Furniss clamp placed to include tent of transverse colon and ileum. Distal ileum to be sacrificed, placed against tent of transverse colon at superior surface of clamp. Proximal ileum to be preserved at inferior surface of clamp.

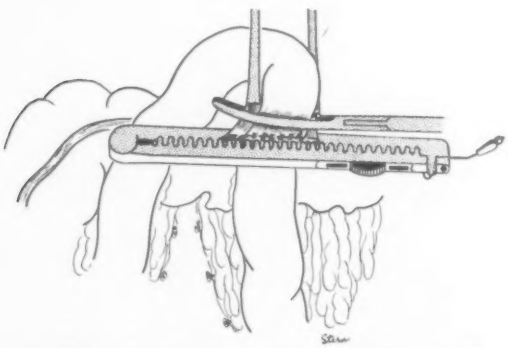

FIG. 18.—Furniss clamp locked and pin passed. Terminal ileum and transverse colon tent ready for excision.

The primary consideration of surgery of the colon is removal of the growth with the regional lymph nodes according to the dictates of good cancer surgery. In addition, the resection must be performed so that an adequate blood supply is available to the severed ends which will be opposed. Figures 1, 2, 3, 4 and 5 illustrate the anatomy of the blood supply of the colon, and the vessels that are preserved for resections at various levels. In 1917, Lockhart-Mummery[19] emphasized that a safer end-to-end anastomosis could be per-

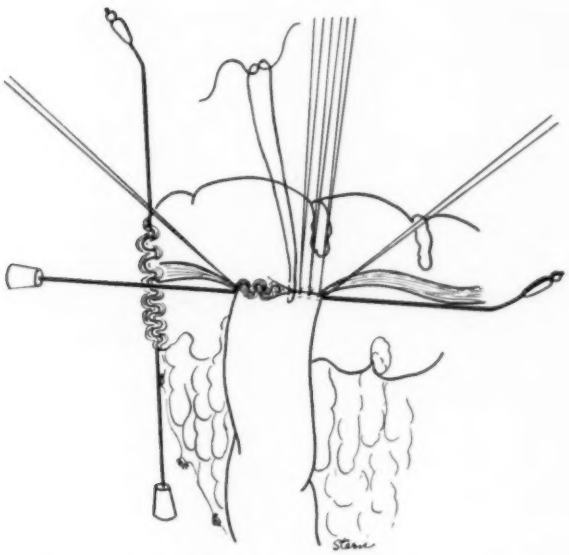

FIG. 19.—Guide sutures applied before removal of clamp. Ileum pinned to transverse colon and first anterior row of interrupted Lembert sutures applied. Specimen excised by placing second Furniss clamp across transverse colon. Aseptic closure of blind end done with Furniss clamp.

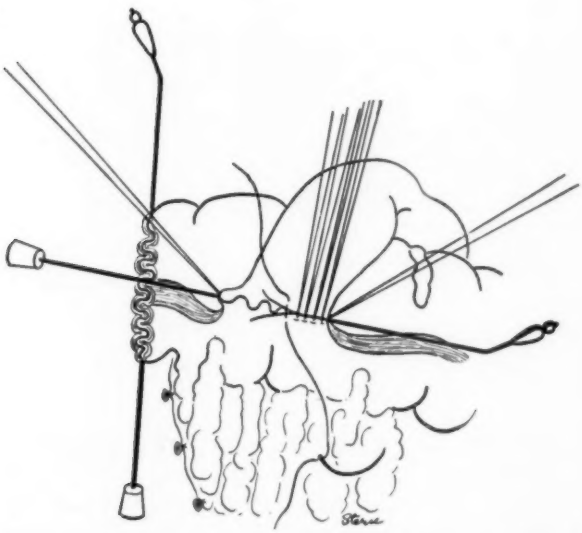

FIG. 20.—Ileum elevated and first posterior row of Lembert sutures placed.

formed if the ends were cut at an angle of 45 degrees from the mesenteric border, due to the fact that the arteries to the antimesenteric tip of the bowel if cut at a 90 degree angle might be insufficient to maintain viability (Figs. 3 and 4). Sealing of an anastomosis occurs by serosal union, hence, excess fat

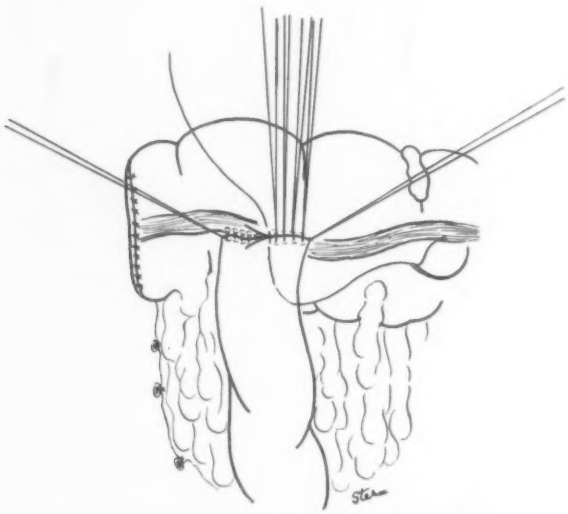

FIG. 21.—Second posterior row of Lembert sutures placed. Stump of transverse colon closed with two rows of interrupted Lembert sutures.

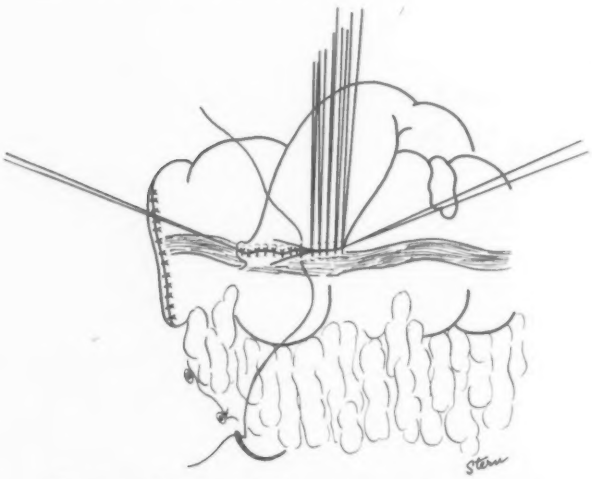

FIG. 22.—Second anterior row of sutures placed.

and appendices epiploicae in the proposed line of suture are carefully removed before the clamp is applied.

The segment to be resected is prepared with these considerations (Fig. 6) in mind. The bowel is rotated 90 degrees, the medial surfaces are opposed

and held with Allis clamps. The Furniss clamp is applied as shown in Figure 7. The clamp is locked, the pin passed, straight clamps are passed across the segment to be sacrificed (Fig. 8), and the colon is resected flush with the Furniss clamp, using a knife moistened with pure carbolic acid (Fig. 9).

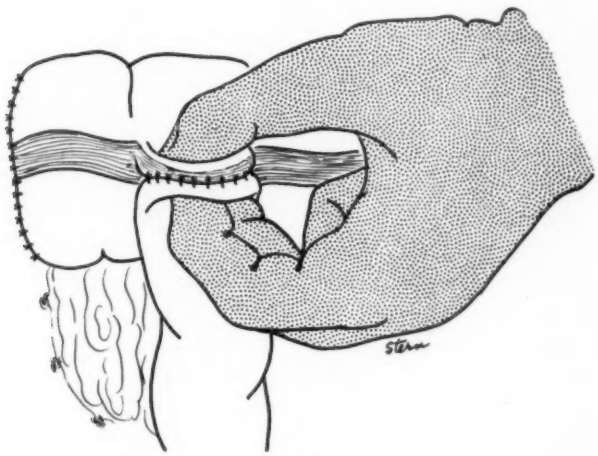

FIG. 23.—Diaphragm opened by manipulation. Patency of anastomosis checked.

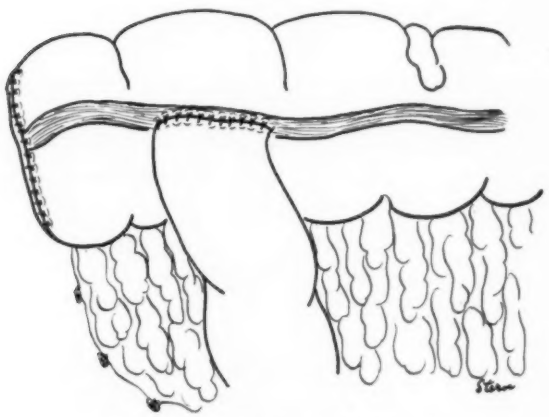

FIG. 24.—Completed anastomosis.

The excess carbolic is removed with alcohol, and the colon is ready for anastomosis. Stay-sutures to take the tension from the intestine and prevent tearing, are placed at the mesenteric and antimesenteric borders, and the clamp removed (Fig. 10). A single row of anterior cotton Lembert sutures is placed (Fig. 10), the intestine is rotated, a posterior row of similar sutures is placed, and the pin is removed (Fig. 11). A second row of interrupted cotton Lembert sutures is placed, and the mesentery repaired (Figs. 12 and 13).

The diaphragm that has been formed by the clamp is opened by manipulation with the thumb and forefinger (Figs. 14 and 15). Sutures are placed down to, but not through, the mucosa. We believe that firmer, faster, and more accurate union is obtained with nonabsorbable sutures.[18] Interrupted fine cotton sutures are chosen for anastomosis, and for closure of the abdominal wall. Drainage of the peritoneal cavity and wound has not been found necessary.

The principle of resection and anastomosis of the right colon is the same although some of the technical steps are different. An end-to-side anastomosis is performed. The Furniss clamp is placed across the ileum and a tented portion of the transverse colon. Care must be exercised to insure that the full-thickness of the wall of the colon is incorporated in the Furniss clamp. This is best accomplished by drawing up a tent of transverse colon with Allis clamps that bite through all the layers (Figs. 16, 17 and 18). The remainder of the technic is illustrated in Figures 19 to 24.

A transfusion of whole blood is administered immediately postoperatively. A Levine tube is left in the stomach, suction is not used. Fluids are permitted by mouth, excess gastric residue siphoned off by the Levine tube. Nutrition is maintained by infusion of amigen and glucose in distilled water. Each liter of amigen contains 2.5 Gm. of sodium chloride, and it is important, therefore, to prevent salt retention and tissue edema by supplying additional fluid as glucose in distilled water. When the patient passes gas by rectum, the Levine tube is removed, parenteral feeding is gradually discontinued, and oral feeding gradually liberalized. Low residue foods are usually tolerated and retained by the third day. Cathartics, rectal tubes, and enemata are avoided. The bowels move spontaneously between the third and fifth days. Occasionally, it has been found necessary to stimulate the lower colon by means of glycerin suppositories. All patients are ambulated on the first postoperative day, and daily thereafter. They are urged to use the bathroom facilities rather than the bed pan. Succinylsulfathiazole is used postoperatively.

CONCLUSIONS

1. One-stage resection of the colon without proximal colostomy is a safe procedure for nonobstructing lesions.

2. The mortality, morbidity, and hospital stay are reduced.

3. Careful preoperative preparation, and attention to details of operative and postoperative treatment are essential for success.

4. We have found that aseptic anastomosis with the Furniss clamp is a satisfactory and simple method.

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AUTHOR'S NOTE: Since the paper was submitted for publication, 24 additional cases have been done: 21 for malignant lesions and 3 for benign lesions. Intestinal complications of these cases: 0; average age: 51 years; average postoperative hospital stay: 13.8 days; mortality: 0 per cent.

TOTAL CASES	COMPLICATIONS (ABDOMINAL)	AVERAGE AGE	AVERAGE P.O. DAYS	MORTALITY
50	6%	46	17	2%

130 E. 79th St.
New York City.

THE ARTERIAL SUPPLY OF THE DISTAL COLON PERTINENT TO ABDOMINOPERINEAL PROCTOSIGMOIDECTOMY, WITH PRESERVATION OF THE SPHINCTER MECHANISM

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THE ARTERIAL PATTERN of the colon has been a fundamental factor in determining the types of surgical procedures which can be successfully applied to that segment of the intestinal tract. In the surgery of the sigmoid and rectum the configuration of the arteries supplying these areas has been a particularly important consideration.

It would seem timely to correlate the design of the arterial supply of the sigmoid and upper rectum with the technic of abdominoperineal proctosigmoidectomy without colostomy and with preservation of the sphincter mechanism because of the increasing interest in this type of procedure. Moreover, Sunderland[9] has recently added significantly to the many important studies of the arteries to the distal colon.

In the development of the present technic of abdominoperineal proctosigmoidectomy with preservation of the sphincter mechanism, extensive precautions have been taken to insure the viability of that portion of the colon which is brought down to the perineum. The feasibility of the operation was first established in animals. In 71 cadavers the vascular supply of the colon and rectum and the mobilization and transplantation of the viable bowel to the anus were proven to be practicable. In every operative case the pattern of the inferior mesenteric artery and its branches was noted by transillumination before any vessels were ligated.

The arterial supply to the segment of the bowel to be transplanted to the anus was observed by the same means after ligation of the inferior mesenteric artery. The distal point of viability was marked with a black silk suture, which facilitated its identification during the perineal phase of the operation. The distal point of viability was brought seven centimeters outside the anus. Viability was further assured by incising small vessels in the mesentery of the bowel and noting free bleeding.

This experience with abdominoperineal proctosigmoidectomy with preservation of the sphincter mechanism in 264 cases (from a total of 407 colon resections) may be considered to have been a method of study of the arteries to the sigmoid and upper rectum. As such, it can be integrated with the experimental anatomic studies.

Sudeck,[8] in 1907, found that the vessels of the rectum became filled with injected material from the inferior mesenteric artery by transversing the

marginal artery when a ligature was placed on the superior hemorrhoidal artery above the origin of the last branch to the sigmoid. If a ligature were placed below the origin of the lowest sigmoidal artery, few, if any, of the rectal vessels filled. In maintaining adequate blood flow to the rectum when the superior hemorrhoidal artery had to be ligated, the origin of the lowest sigmoidal artery became known as the critical point of Sudeck. Two years later Hartmann[3] corroborated Sudeck's findings and remarked that in the perineal excision of the rectum with transplantation of viable bowel to the perineum, the superior hemorrhoidal artery must be ligated high on the common trunk above the last anastomotic loop. He further commented that this ligation could only be performed through an abdominal approach. Sunderland[9] pointed out that in the illustration used by Hartmann, the lowest sigmoidal artery was not shown and that the point of ligation indicated by Hartmann was quite high on the inferior mesenteric artery. Archibald,[1] in 1908 demonstrated by animal experiments and postmortem dissections the significance of the marginal artery and proved to his satisfaction that the rectum and pelvic colon could be resected and viable iliac colon successfully brought down to the anus. Rubesch,[5] in 1910, also using an injection method, found that the lowest sigmoidal artery, the sigmoid ima, may arise from the superior hemorrhoidal after it has bifurcated. Thus, the critical point may vary from 13 to 20 cm. from the anus. Drummond,[2] in 1914, studied roentgenologically the injected inferior mesenteric artery in 20 specimens. In 40 per cent of the cases the last sigmoidal artery and its proximal anastomosis were insignificant and in another 20 per cent of the cases the artery was not even present.

Steward and Rankin,[7] on the basis of an extensive study of 100 injected specimens, described a gap in the bowel between the termination of the marginal artery and the bifurcation of the superior hemorrhoidal artery. This segment was found to be supplied by one to five small arteries which arose from the superior hemorrhoidal artery and which varied in size and number with other anatomic variations in this region, that is, a high, low or absent last sigmoidal artery or a low bifurcation of the superior hemorrhoidal artery.

Sunderland[9] dissected the arteries to the distal colon in 20 specimens and studied the injected arteries of five additional specimens roentgenologically. The fact that he used dissection as well as the injection method, whose results may be open to question (Rankin and Graham[4]), may account for the variation between his studies and those of other workers.

The number of sigmoidal arteries was found by Sunderland to vary from one to seven in number. They did not form any definite or constant pattern. Our operative experience has been similar. The configuration of the inferior mesenteric artery and its branches must be determined in each case by transillumination of the mesentery. Only in this way can the proper point for ligation be established, consistently. Thus, on the basis of studies of cases at operation, we have confirmed the recommendation of both Sudeck[8] and Hartmann[3] that it is wise in each patient to observe the arterial pattern of the inferior mesenteric artery and its branches.

When present, the lowest sigmoidal artery was found by Sunderland[9] to descend vertically to the rectosigmoid and supply the upper portion of the rectum which is also supplied by the superior hemorrhoidal artery. This is at variance with the findings of Steward and Rankin[7] which have been stated previously. Sunderland found Drummond's[2] statements concerning the relationship between the superior hemorrhoidal artery and the lowest sigmoidal artery less than explicit. The former demonstrated that the two vessels overlap in their supply of the upper rectum but in only five of 25 cases was there any anastomosis.

In the technic of abdominoperineal sigmoidectomy with preservation of the sphincters, the last sigmoidal artery may be disregarded whether one accepts the views of Steward and Rankin or Sunderland. The superior hemorrhoidal artery cannot be ligated below the origin of this vessel and allow sufficient mobility of the bowel to permit its being brought down to the anus without tension. As a corollary, it is impossible in performing this operation to clamp the superior hemorrhoidal artery at the critical point of Sudeck.

Sunderland[9] discovered that there was a well-marked anastomosis with a continuous vascular arcade (marginal artery of Drummond) between all sigmoidal arteries. He remarked, however, that his findings disagreed with those of Drummond[2] who found the lowest sigmoidal artery and its proximal anastomosis to be insignificant in 40 per cent of the cases and the artery to be absent in another 20 per cent of the cases. In view of this discrepancy, Sunderland believed it prudent to ligate the inferior mesenteric artery at a level higher than that between the lowest two sigmoidal arteries; there has been general agreement regarding the competency of the arterial anastomosis above this level. In our operative experience we have been able to segregate those cases in which ligation may be made safely between the lowest two sigmoidal arteries from those in which ligation must be performed higher than the second lowest sigmoidal artery to assure viability by the simple precautions previously described. Chief among these measures has been transillumination of the mesentery before and after ligation of the inferior mesenteric artery.

Sudeck's[8] critical point has been shown to vary with the individual pattern of the arteries to the lower sigmoid. It varies with the type of surgical procedure to be performed. In the Miles-type of operation viable bowel must be brought out as an abdominal colostomy. As shown by Singleton,[6] this should present no difficulty when the inferior mesenteric artery is ligated above the lowest sigmoidal branch. On the bases of the anatomic studies which have been described, if there is doubt regarding the adequacy of the blood supply to the colostomy loop, ligation need only be done above the second sigmoidal artery to insure sufficient blood flow. Drummond[2] stated that where a permanent colostomy is done, the inferior mesenteric artery may be ligated just below the origin of the left colic artery.

In an end-to-end anastomosis following resection of the sigmoid, viability of each end must be assured. It is in this operation that the critical point is most significant; indeed a hypothetic situation could arise in which the rad-

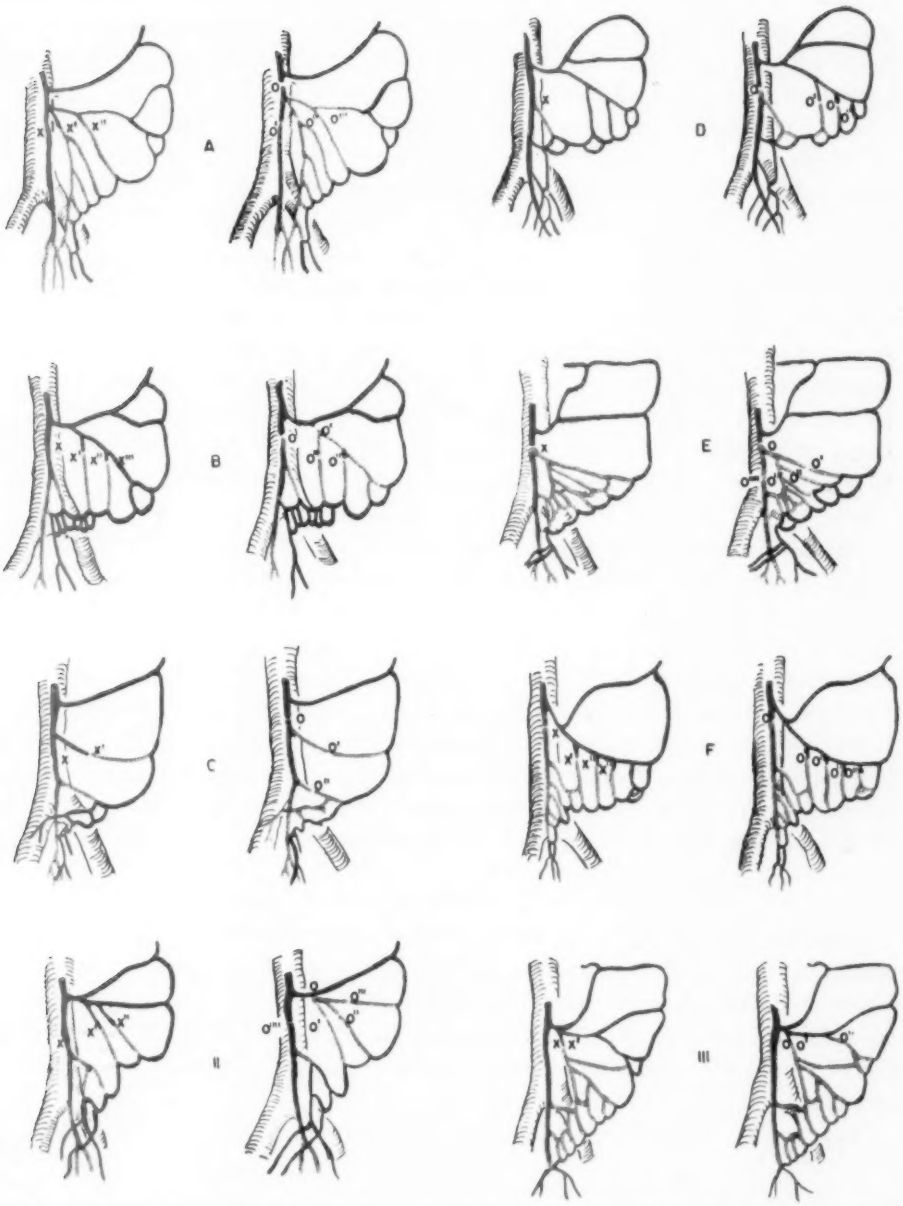

PLATE 1.—Drawings, adapted from Sunderland, of the aorta, the common iliac arteries, the inferior mesenteric artery, the left colic artery, the sigmoidal arteries and the superior hemorrhoidal artery in each of eight patients (A, B, C, D, E, F, II, III). The preferred and acceptable alternate points of ligation of the inferior mesenteric and sigmoidal arteries are indicated by X, X′, X″, X‴ and O, O′, O″, O‴, O⁗ respectively. The points also outline that portion of the sigmoid mesocolon and lymph gland bearing tissue which will be removed during the perineal phase of the operation. The route of the preserved blood supply to that portion of the bowel which is to be transplanted to the perineum is denoted by red. The interrupted arterial pathways are indicated by blue. (Bacon & Smith)

icalness of the resection might be compromised to attain viability of the bowel ends. A detailed discussion of the relationship of this operation to the arterial blood supply of the distal colon is beyond the scope of this paper. The reader is referred to Sunderland's discussion of this topic.

As has been shown, in performing abdominoperineal proctosigmoidectomy with preservation of the sphincter mechanism, the critical point of Sudeck need hardly be considered. Ligation of the inferior mesenteric artery must be performed above the lowest sigmoidal artery at least to permit the mobility of the colon necessary to bringing it to the anus. Furthermore, the inferior mesenteric artery may be deliberately ligated much more proximally in cases where more of the upward lymphatic pathway is to be removed or where one is not completely satisfied with the competency of the circulation to that portion of the bowel to be brought to the anus. In the average case we have agreed with Drummond that the most convenient place to ligate the inferior mesenteric artery is immediately below the first sigmoidal branch, which can be recognized by the large anastomotic branch it forms with the left colic artery.

In selected cases of polyposis, ulcerative colitis, diverticulitis, and lymphopathia venereum, the rectum, sigmoid, descending colon, splenic flexure and a portion of the transverse colon have been excised. In these cases all branches of the inferior mesenteric artery have been ligated and the stump of transverse colon has been brought down to the perineum. Viability has been maintained by the middle colic artery. These patients are the basis of a separate report.

The blood supply to the rectum beyond the bifurcation of the superior hemorrhoidal artery presented no controversial points and its discussion has been omitted. The blood flow to the preserved sphincter muscle and anal skin is abundant by way of the internal pudendal arteries.

SUMMARY

A review of the anatomic studies of the arterial supply of the distal colon and a correlation of these studies with the technic of abdominoperineal proctosigmoidectomy without colostomy and with preservation of the sphincter mechanism have been presented. The operative measures which, in our hands, have insured the transplantation of viable bowel to the perineum have been presented.

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SURGICAL TREATMENT OF CARDIOSPASM

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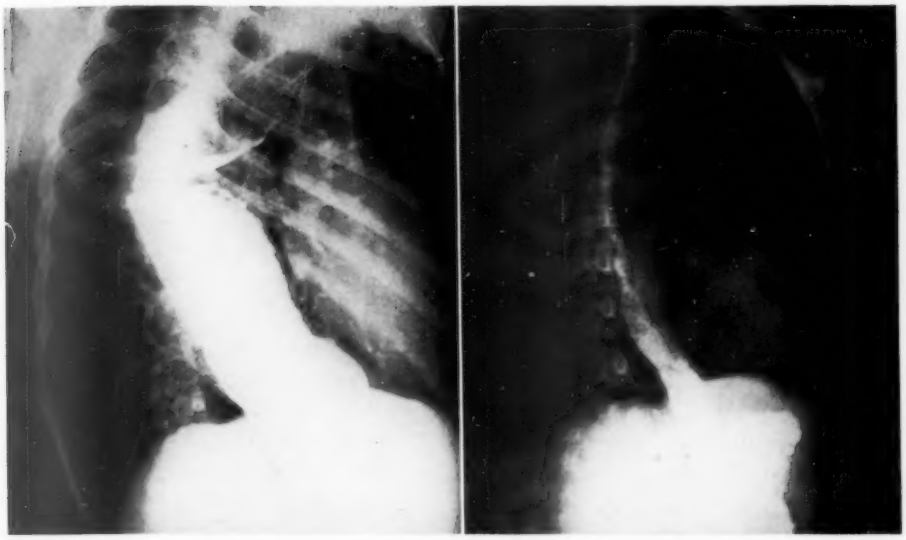
THOUGH MANY PATIENTS with cardiospasm receive symptomatic improvement for varied periods of time following instrumental dilatation of the esophagogastric junction, the benefit obtained is rarely complete or permanent. No evidence of reduction in the size of the esophagus following dilatation has ever been presented. In some patients the tortuosity of the esophagus prevents instrumentation and in others no significant improvement results from this therapy.

The operative procedures designed for relief of this condition have been as varied as the theories presented as to its pathogenesis and have been directed at the dilated esophagus, the cardia, its nerve supply, and the diaphragm. Though isolated reports of successful results from each of these methods have been published, the majority of these technics have not been universally satisfactory. Of all operative procedures, those technics directed at the esophagogastric junction in which the size of this stoma is enlarged, appear to have given the best results. Even after these operations it has usually been stated[1, 2, 3] that the functional results were better than the roentgenologic evidence of improvement. Considerable discussion has also been presented regarding the relative merits of the transabdominal and the transpleural approaches. Most opinions have favored the transabdominal approach, in that this was felt to be associated with less risk.

The purpose of this paper is the presentation of the surgical technic employed and the postoperative results in 17 patients having transpleural cardioplasties who had not been significantly improved by instrumental dilatation. This group of patients is of interest not only because of the symptomatic improvement but also because of the marked reduction in the size of the esophagus postoperatively (Figs. 1, 2 and 3).

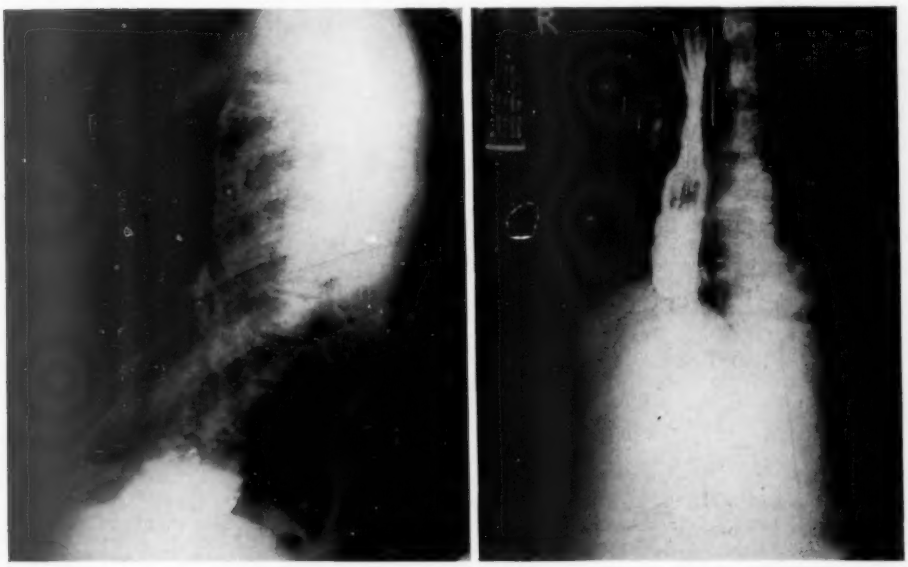
All of the cardioplasties were performed through a transpleural approach, for it was felt that this allowed better exposure of the esophagogastric junction, better mobilization of the lower esophagus and cardia of the stomach and, in turn, the construction of a larger aperture than would be possible through an abdominal approach. The new stoma was made large enough to allow for its reduction in size as the caliber of the esophagus decreased. The size of the stoma determines the ease with which the esophagus empties itself and the likelihood of its reduction in caliber.

The first three cardioplasties were performed in a manner similar to a Finney pyloroplasty technic, the others in a manner similar to a Heineke-Mikulicz pyloroplasty technic. The latter type was found to be the easier and



A B

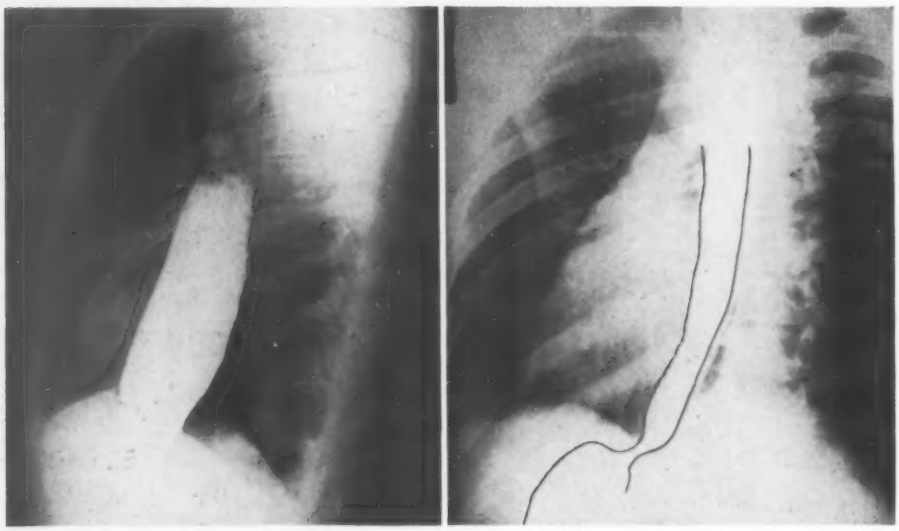
FIG. 1—Esophagograms before (A) and six weeks after cardioplasty (B).



A B

FIG. 2.—Esophagograms before (A) and six weeks after cardioplasty (B).

more satisfactory procedure. This technic was first employed by Wendel,[4] in 1910. As illustrated in Figure 4, the lower esophagus is mobilized and carefully inspected. The diaphragm about the diaphragmatic hiatus is incised



A B

FIG. 3.—Esophagograms before (A) and two months after cardioplasty (B).

radially for three to four centimeters to allow examination of the diaphragmatico-esophageal ligament and its attachment to the esophagus and esophagogastric junction.

Care is exercised to excise any limiting bands in this ligament. This ligament appeared responsible for the esophageal obstruction in five patients.[5] In the first patient upon whom this observation was made, the diaphragm was incised lateral to the hiatus and the lower esophagus retracted into the abdomen. The diaphragmatico-esophageal ligament appeared markedly hyper-

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FIG. 4.—(A) The lower esophagus and esophagogastric junction have been mobilized. The diaphragmatic hiatus has been enlarged and the diaphragm inverted exposing the diaphragmatico-esophageal ligament of its under surface as it is inserted into the esophagogastric junction.

(B) The diaphragmatico-esophageal ligament has been separated and the peritoneal reflection incised. The cardia of the stomach has been retracted into the thoracic cavity. The esophageal and cardial lumina have been occluded by umbilical tape. Two constrictions in the lower esophagus and esophagogastric junction at the sites of insertion of the diaphragmatico-esophageal ligament are apparent.

(C) A large longitudinal incision has been made through the esophagogastric junction and extended in both directions. A section of this junction was taken for microscopic study.

(D) The above incision is closed transversely by a mucosal layer of continuous catgut suture and an outer layer of interrupted black silk sutures.

(E) The new stoma has been replaced into the abdomen and a new diaphragmatic hiatus made by suturing the diaphragm about the esophagus at a higher level.

FIG. 4

trophied and taut as it was inserted into the lower esophagus. All of the visible portion of this ligament was incised at its insertion about the esophagogastric junction and lower esophagus. A Finney-type cardioplasty was then performed. Postoperatively, he still noted dysphagia and esophagograms again demonstrated obstruction at this site. Consequently, an abdominal exploration was done ten days postoperatively. The new stoma appeared widely patent and no abnormality could be found. An incision was then made in the anterior surface of the stomach and a finger was inserted into the esophagus where a button-like stenosis was encountered. This was retracted into the abdomen and found to be caused by a constricting band in the uppermost portion of the diaphragmatico-esophageal ligament that had not been severed at the first operation. The esophageal occlusion was immediately relieved as soon as this was incised. In one other patient, the anterior portion of this membrane was band-like in character and appeared to cause constriction, this was completely cut and marked improvement was noted postoperatively. The esophagus in this patient, however, did not decrease in caliber to the same extent as that noted in other patients upon whom cardioplasties were also performed. In seven other patients the diaphragmatico-esophageal ligament appeared normal but considerable periesophageal fibrous bands were in close contact with this ligament and adherent to the longitudinal musculature of the esophagus. It is now felt that this site can be best inspected by enlarging the diaphragmatic hiatus and retracting the cardia of the stomach into the thorax.

The peritoneum is incised and the cardia mobilized and retracted into the thorax. The esophageal and gastric lumina are occluded by umbilical tape to prevent spillage. A longitudinal incision is made through the esophagogastric junction and extended in both directions for approximately four inches. A section is frequently taken at this site for microscopic examination. This opening is closed transversely by an inner layer of running catgut suture followed by an outer layer of interrupted black silk suture. Approximately 100,000 units of penicillin are injected about the stoma. The stomach and new stoma are replaced into the abdomen and a new hiatus made by suturing the diaphragm at a higher level upon the esophagus. This also aids in straightening the esophagus. The chest is closed without drainage. The only postoperative complication to date has been a transient collection of serum requiring one to two pleural aspirations in four patients. Hourly feedings of milk are provided as soon as the patient awakens from the anesthesia but an inlying Wangensteen suction is employed and clamped intermittently for three days. The usual postoperative gastric diet is then provided. These patients have been able to note the sensation of food and fluids going immediately into the stomach upon swallowing, a sensation that they had not experienced for many years.

SUMMARY

The surgical technic employed and the operative results obtained in 17 patients having transpleural cardioplasties who had not been significantly

improved previously by instrumental dilatation is presented. In each patient there was a marked reduction in the size of the esophagus postoperatively.

All of the patients were convinced of the greater relief accorded by operation as compared to instrumentation. It can be argued from this that many patients with cardiospasm may exist for years with partial benefit from instrumentation who do not realize the more complete and permanent benefit that might be derived from operation.

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SPONTANEOUS RUPTURE OF THE MALARIAL SPLEEN

CASE REPORT AND ANALYSIS OF 64 REPORTED CASES

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SPONTANEOUS RUPTURE of the malarial spleen is a rare but dramatic complication demanding prompt recognition and surgical treatment. With the large numbers of cases of malaria in military service, traumatic and spontaneous rupture of these enlarged and friable spleens has been reported ten times in the past five years. In many instances, clinical malaria occurs only after cessation of atabrine and return to civil life. Best and Schmid[1] recently reported three cases and collected 35 (including nine inoculated syphilitics) in the literature from 1920 to 1945. Kaplan, *et al.*[30] reported a case occurring in an inoculated paretic and listed 31 similar cases. In our review of the American and foreign literature since 1917 we have found 64 cases of spontaneous splenic rupture in inoculation and naturally-acquired malaria.[1-53] Seventy-two cases prior to 1917 were reviewed by Leighton.[54]

Because large numbers of cases of malaria will relapse in communities where the disease is unfamiliar, and because only early diagnosis and prompt treatment will lower the present high mortality, we believe a report of our case and a review of the literature is timely. Also, there are important clinical differences between the syndrome occurring during malarial treatment of syphilitics and in naturally-acquired malaria which are not generally appreciated.

Case Report.—No. 19505: This 37-year-old veteran was brought by ambulance, January 2, 1946. Because he was semiconscious, history, at first, was obtained chiefly from his wife.

CC. Weakness, collapse, and epigastric pain of several hours duration.

PI. The patient had served 31 months in the South Pacific, taking atabrine 0.1–0.2 Gm. daily. Twenty days before admission he arrived in the continental limits of the United States and stopped atabrine.

Five days before admission he developed fever, shaking chills, generalized aches and pains, severe headaches, and his head and nose felt "all stopped up." Four days before admission he became nauseated, and he vomited four to five times daily thereafter, and vomitus had occasional flecks of red blood. He had much epigastric soreness. There were no blows, falls or even minimal trauma, recent or remote. Because of fever and malaise he remained in bed after the first few days.

Several hours before admission he vomited and shortly thereafter, while in bed, experienced a severe, sudden epigastric pain which caused him to cry out, draw up his knees and faint. When he quickly recovered consciousness, he remained weak, complained bitterly of pain in the upper abdomen. No pain in the shoulder or elsewhere.

FH. PH. and system review. Noncontributory.

PE. A well-developed, well-nourished young man in collapse, pale, sighing, restless and apathetic.

T. 104° F. by rectum; pulse 110 and barely perceptible.

BP. 70/50. R.24.

Once during examination he became unconscious and was resuscitated with oxygen inhalations, plasma infusion and intravenous stimulants. The significant positive and negative findings were as follows: The abdomen had slight rigidity everywhere, but there was marked tenderness and spasm in the left upper quadrant near the costal margin. The spleen could not be felt due to spasm. There was no audible peristalsis. No distention.

The remainder of the physical examination was negative, except the marked atabrine pigmentation of skin, sparing the sclerae. Extremities were cool. Neck supple, brisk neurologic examination negative. Heart and lungs normal.

While awaiting reports from the laboratory and blood for transfusion, the treatment given was morphine sulphate 10 mg. subcutaneously, plasma 500 cc. intravenously. When P. *vivax* was reported on smear, quinine dihydrochloride 0.25 Gm. intravenously, diluted in 250 cc. normal saline was started but soon replaced with plasma and atabrine 0.4 Gm. substituted intramuscularly.

Laboratory Data.—White blood count 5,000, with 44 per cent segmented and 32 per cent band-like neutrophils, 20 per cent lymphs, hemoglobin 13 Gm. per cent. Numerous P. *vivax* were seen on thick and thin smear. Some parasitized cells were slightly enlarged. Thick drop showed many small and large trophozoites, rare presegmenting schizonts, but no gametocytes. Urinalysis showed 10 mg. per cent albumin, but was otherwise negative. No hemoglobinuria. Chemical test for urinary atabrine was negative.

Diagnosis.—While blood for transfusion was awaited the generalized abdominal spasm became more marked. These signs of spreading peritoneal irritation following sudden shock, with severe pain spasm and tenderness in the splenic region of a man with malaria, caused the diagnosis of spontaneous rupture of the spleen. Five hundred cubic centimeters citrated blood was given intravenously and the blood pressure rose to 105/60, so operation was begun.

Operation.—(Dr. O. C. Williams)*. Eight hours after onset, under nitrous oxide-oxygen-ether anesthesia, the abdomen was opened through a muscle-splitting incision of the left upper rectus. The peritoneal cavity was entered, and 600 cc. liquid blood removed by suction. A large clot, the equivalent of another 500 cc. of blood, lay over the spleen. The enlarged and ruptured spleen was readily removed.

Postoperative Course. At the end of the operation the blood pressure fell to 80/60, and the pulse rose to 160. Two 500 cc. transfusions were given simultaneously with good response and followed by a third. Two hours postoperatively the blood pressure was stabilized at 140/100. The usual postoperative management was followed, with addition of atabrine 0.2 Gm. i.m.q. four hours for six doses, and thereafter 0.1 Gm. was given daily for another few weeks. Several malaria smears were negative, and the fever gradually subsided, but the temperature was not normal until the 30th day. Hemoglobin rose to normal, repeated smears and white blood counts were unremarkable. The patient was discharged well on the 30th hospital day.

Pathology Report.—Gross: The spleen was enlarged (Fig. 1), measuring 15 x 10 x 5 cm., and weighing 380 Gm. On the convex surface the capsule had been stripped away over a large area, uncovering the underlying irregular, raw, splenic tissue. In the central portion of this exposed surface there was an irregular, funnel-shaped rent in the pulp, measuring 8 mm. in the diameter and 2 to 3 mm. in depth. Submitted with the specimen was a large blood clot representing approximately 400 or 500 cc. of blood. The remaining intact capsule was tense. On section, the splenic tissue was found to be moderately soft, dark red in color, bulging above the cut surface. A small amount of moist, soft, red

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tissue could be scraped from the surface. The malpighian follicles were not grossly apparent.

Microscopic: Sections were taken from the vicinity of the tear on the convex surface as well as from other areas in which the capsule was intact. The tissues were stained with the hematoxylin-eosin, van Gieson, Romanowsky, Giemsa, iron pigment, and reticulum stains. All sections showed essentially similar changes, including those from the site of rupture as well as those removed from other regions. Surrounding the rupture the capsule was stripped away, leaving only a thin single layer of connective tissue as a covering. Elsewhere, the capsule was covered by a fine, fibrinous deposit.

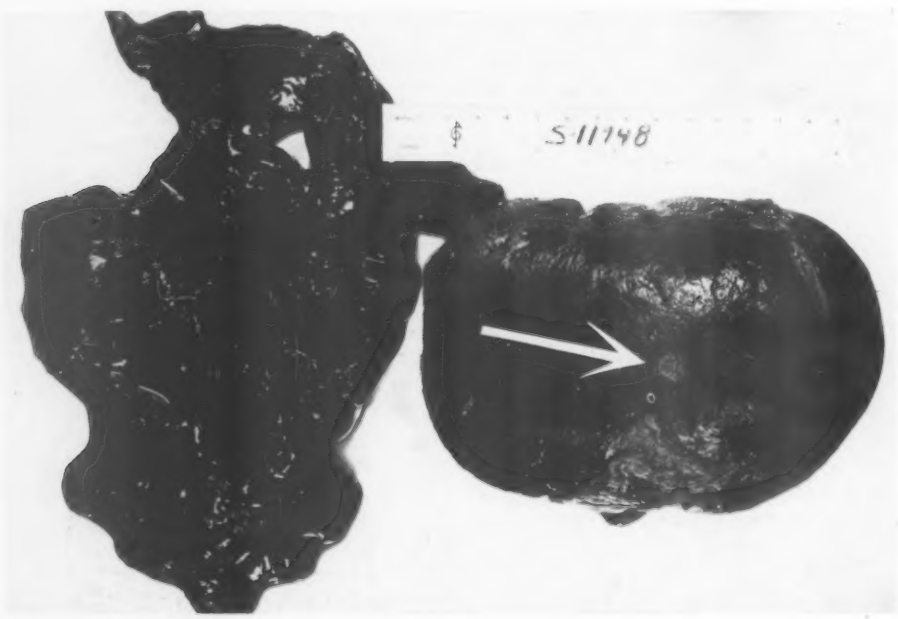

FIG. 1.—Ruptured spleen in acute malaria; spleen enlarged, soft; arrow points to site of rupture.

The follicles were enlarged but inconspicuous, merging diffusely with the red pulp, due to the general cellularity of the entire organ. The germinal centers were enlarged and pale. Their constituent cells were loosely arranged, separated by a pinkish-staining, amorphous, ground substance resembling coagulated edema fluid. The cells were varied—some being enlarged, pale-staining reticulum cells—others, small lymphocytes, were darkly stained, apparently undergoing degenerative changes. There were also nuclear fragments. Mitotic figures were occasionally found. The pale central zone was sharply demarcated against the peripherally-located portion of the follicle. The latter was large and contained the usual lymphocytic cells, although mitoses were frequently seen.

The *red pulp* was extremely cellular, the cells being of varying types. By far, the most prevalent were the large reticulum cells found within the widened splenic cord. These showed storage of two types of pigment: fine granules taking the iron stain (blood pigment); and coarse dark brown grains (malarial pigment) which had no affinity for the iron stain. The endothelial cells lining the sinusoids were numerous and hyperplastic, projecting into the lumen or desquamating completely into it. Several of these cells contained pigment similar to that found in the reticulum cells. Plasmodia could not be identified within any of the nucleated cells.

The sinusoids (Fig. 2), for the most part, contained few red cells but were completely engorged with white cells. These appeared to be mostly desquamated endothelial cells. However, they also contained numerous macrophages, often large and multinucleated, which contained iron pigment as well as large, coarse, granules, similar to that found in the reticulum cells. Occasionally, polymorphonuclear cells were also present.

FIG. 2

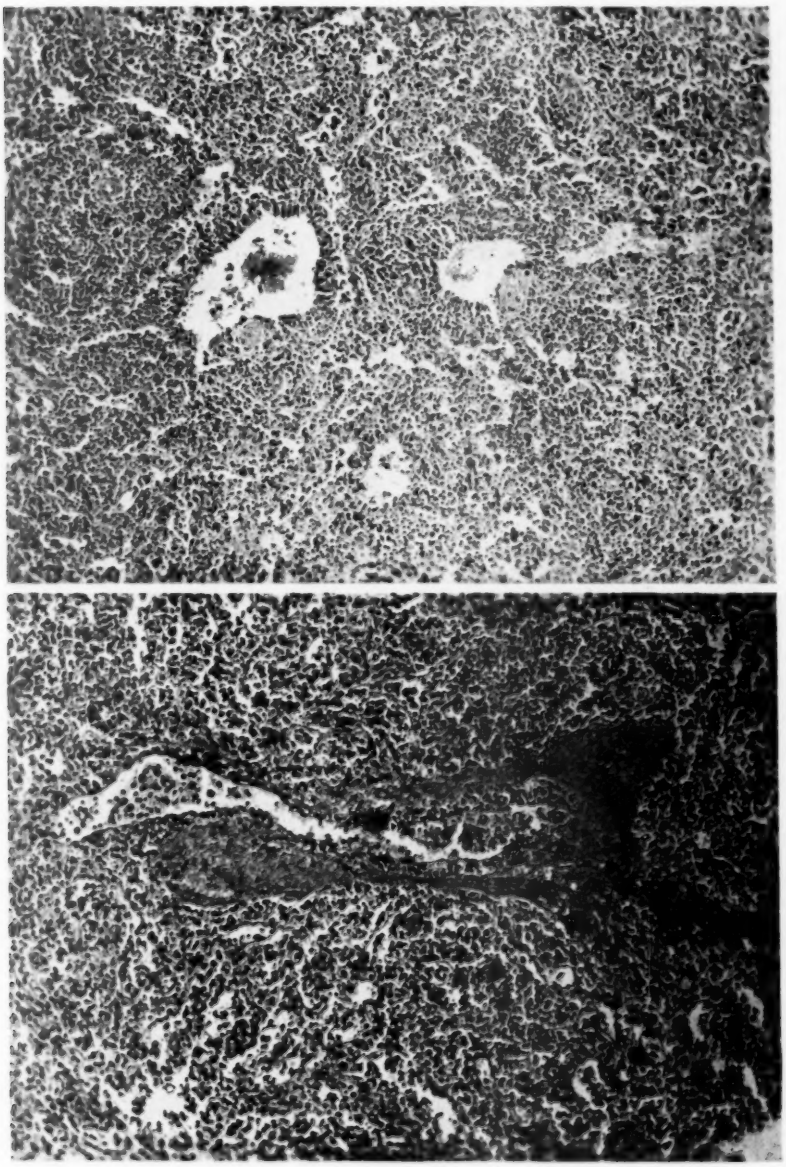

FIG. 3

FIG. 2.—*Sinusoids:* Some are dilated, others are engorged with microphages.
FIG. 3.—*Veins:* Dilated, filled with macrophages. On the right a thrombus is in the process of formation. Subendothelial myelopoiesis.

Conspicuous was the enormous dilatation of some of the sinusoids. Some contained the aforementioned cells; many, however, were engorged with red cells. These cells lay close against the wall and were continuous with the cord cells. Occasionally, the entire mass was converted into a thrombus. The sinusoidal wall here was indistinct or lacking.

Veins: Many were dilated (Fig. 3), and filled with cells similar to that found in the dilated sinusoids. Thrombus formation was also apparent. Immediately under the endothelial layer the tissue was loose and a thin layer was formed containing macrophages and monocytes, with some phagocytosis of pigment. Essentially, the cells were similar to that found in the splenic cord and in the sinusoids.

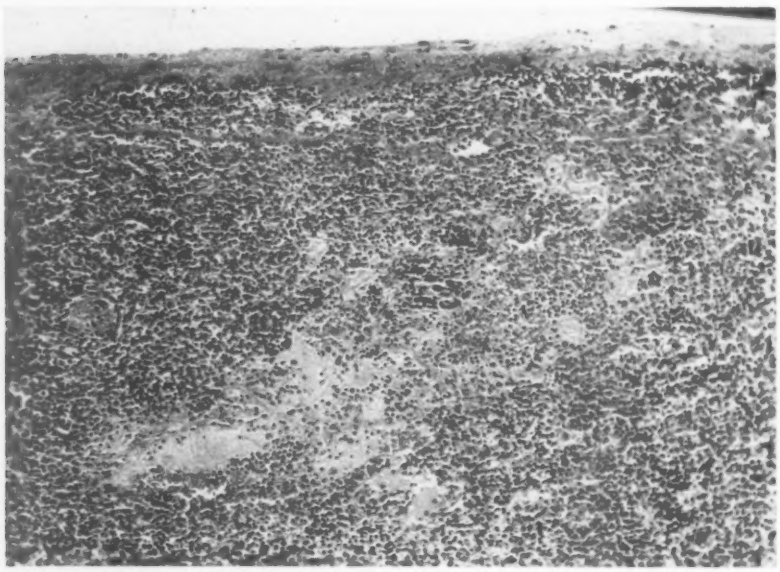

FIG. 4.—Splenic infarction, subcapsular. Thrombosis, infarction and necrosis.

In many portions of the spleen, but particularly under the capsule, a peculiar degenerative change was noted (Fig. 4). Associated with a dilated thrombosed vein or sinusoid, there was complete disruption of the architecture of the sinusoids and the cord. The tissue was an admixture of all of these cells, including red cells, hemolyzed blood, degenerating white cells and a pinkish-staining amorphous fibrinoid substance, all merging into a poorly-defined conglomerate. Numerous areas of this type were found under the capsule.

Scrapings from the fresh organ stained with Wright and Giemsa stains showed rare mature trophozoites of P. *vivax* within the red cells. No parasites were found within any of the white cells or macrophages.

The 64 cases in the literature since 1917 are listed in the bibliography.[1-53] There were no case reports, merely mention of their occurrence in many instances.[40-49] Some articles were not available to us.[19-22 and 50-53] Many case reports were incomplete; some had no pathologic or microscopic examinations performed. However, we have read and tabulated such data as was presented in cases listed in bibliography.[1-18 and 23-29] Fairly detailed reports were available in some instances, and are the sources of the data in the section on the

clinical features in spontaneous rupture. One case was reported separately by two authors.[24, 25] Several authors recorded two cases.[18, 39, 28, 40, 42, 47, 43] Two men observed three cases.[1, 46]

INCIDENCE

The occurrence of spontaneous rupture in allegedly normal spleens is rare. A few instances have been reported in each of 16 different diseases accompanied by splenomegaly. By far, the most common cause of spontaneous rupture is malaria. Since Leighton's review, 25 cases of spontaneous rupture have been reported in naturally-acquired malaria.[1-22] Thirty-nine cases have occurred since malaria was first induced for treatment.[23-53]

TABLE I

INCIDENCE OF SPONTANEOUS RUPTURE OF SPLEEN IN INOCULATION MALARIA

De Cary	2:274	
De Asis	2:101	
Wile	1.1026	
Moore	2.1600	
Fong	2:1012	
Driver, *et al.*[11]	0:2479 (review)	
Cantacuzene	1:528	
Dattner	0:5000	
Total reported inoculation cases in literature		39
Total reported cases naturally-acquired malaria (1920-1946)		25

The incidence of spontaneous splenic rupture in induced malaria is shown in Table I, and does not include unreported or unrecognized instances. This is considerably higher than the incidence in naturally-acquired malaria, probably because of the preëxisting splenic pathology,[55, 56] the older age, and the longer duration of the malaria without specific treatment.

With only two exceptions,[51, 24] all inoculations were for treatment of central nervous system syphilis. Spontaneous rupture has occurred as early as two days after the onset of symptoms, and a third of our present series occurred later than 15 days. However, in a series of 5,000 cases which were interrupted after eight chills, no cases of rupture of the spleen occurred.[57]

Traumatic rupture of the spleen is very frequent in malarious climes. Because of great enlargement, exposed position, congestion and friability, malarial spleens are readily ruptured by minimal trauma, and in one region 1/30th of all deaths are allegedly caused in this way.[58] In Berger's review[59] (1902) of 123 cases of traumatic rupture of the spleen, 93 had malaria.

Spontaneous rupture of the spleen in naturally-acquired malaria is rare. It is estimated to occur once per 100,000 infections by Manson-Bahr. In the Canal Zone, it occurred three times in 30,000 hospital admissions,[60] and in three of 100 malarial deaths.[61] It causes 4.45 per cent of all malarial deaths in one section of India (Massari). Although it is a rare complication, prompt diagnosis and treatment will save some persons who would otherwise certainly die.

SPECIES AND STAGE OF MALARIA

Spontaneous rupture has been reported with all species except P. malariae. The great majority are P. *vivax,* which was found pre- or postoperatively in 16 of 19 cases in which species was stated. It may be assumed that the great majority of inoculations were P. *vivax,* even when not specifically stated. Two cases were P. *falciparum,* and one, P. *ovale.* Multiple ring forms were not observed in the P. *vivax* from our case. The species or strain made no difference in the clinical picture of the reported cases.

Superinfection, or degree of parasitemia, apparently, was of little consequence, since four cases occurred during afebrile or chronic stages of the disease. In no case of active malaria was it remarked that the paroxysms, or other features, were more severe than usual. However, some cases had much vomiting, diarrhea or delirium.

PATHOLOGY OF SPLENIC RUPTURE IN ACUTE MALARIA

The pathology of the spleen in acute malaria in humans is well-reviewed by Taliaferro and Mulligan,[63] and by Ash and Spitz,[62] and our specimen revealed the changes reported. The alterations of sinusoids and veins were very noticeable in our case, however. Otherwise, the phagocytic, degenerative and hyperplastic changes were those well-recognized in acute malaria.

The sinusoids and veins are dilated and filled with macrophages and blood cells. The trabecular veins form a layer of reticulum cells under the endothelium and, less commonly, under the adventitial layer, similar to that found in the splenic cord. Within the pool caused by the dilated veins and sinusoids, the macrophages, red cells and even polymorphonuclear cells lie in a pinkish-staining fibrinoid material resembling a thrombus. These aggregates lie so closely against the wall that it is often difficult to determine whether they project from the cords. Rigdon[64] believes that the hyperplastic splenic pulp actually protrudes into the sinusoids. Thrombi formed in the arterioles, capillaries, veins and sinusoids are associated with hemorrhage, necrosis and infarction. Subcapsular splenic hemorrhages in acute malaria are frequent.

PATHOLOGIC FINDINGS IN REPORTED CASES OF SPONTANEOUS RUPTURE

Of the 58 cases of spontaneous rupture of the spleen in malaria, which have been available to us, only 29 include any sort of pathologic description. The pathologic findings in both types are similar and conform to the best literature.[62, 63] There were no significant differences related to the species.

Grossly, the spleen was enlarged in all but one case, but because average weights were 450–500 Gm., many would not have been palpable. Hemoperitoneum had occurred in all but one case,[36] and was due to rupture of the splenic capsule with only two exceptions. In one instance, an accessory spleen had ruptured,[2] and in another case a hole was found in a tiny hilar vein.[1] In every instance, the slight to moderate enlargement and the color and consistency were typical of acute malaria.

Despite older statements, rupture of the capsule had no predilection for

convex or posterior surface. Presence of adhesions to the diaphragm were noted in four cases, and by limiting equal expansion of the spleen this may have contributed to the rupture. In 25 cases the number of tears was noted. Three spleens had burst into fragments. Nine others had multiple tears. That the initial step in rupture of the capsule is frequently formation of subcapsular hematomas is indicated by their occurrence in five cases. In three cases, rupture of the subcapsular hematoma occurred during surgical manipulation.[18, 24, 1]

More or less complete microscopic descriptions are reported in 16 cases. These follow the general description of the spleen in acute malaria, as indicated above. Nine cases described vascular changes; in two, this was apparent grossly as anemic infarcts. Microscopically, all nine showed foci of interstitial hemorrhage and occasionally thromboses and infarcts, similar to our case, or as described by Rigdon.[64] We believe these interstitial subcapsular hemorrhages and infarctions result from endothelial swelling and subintimal infiltrations in small veins.

PATHOGENESIS AND MECHANISM OF RUPTURE

The mechanism of rupture of the normal and enlarged spleen may be threefold: (1) local lesions as points of weakness; (2) increase of tension due to hyperplasia and engorgement; and (3) compression by the abdominal musculature.

Because the exact site of initial subcapsular bleeding or capsular rupture cannot usually be identified and may be destroyed in the process of rupture, the etiologic rôle of local lesions must be inferred from the presence of similar lesions elsewhere in the spleen.

The spleen, even in normal persons, is frequently the site of pathologic changes that predispose it to rupture. Arteriosclerotic alterations of vessels may result in "splenic apoplexy" (Ask-Upmark).[73] Adhesions and thickenings of the capsule may prevent equal expansion and accommodation to increased tension. One case in this series had calcareous deposits in a large part of the capsule which had ruptured at another weaker and expanding site.[36] Contusions may cause subcapsular hematomas, later organized into blood cysts. It is perhaps in this way that trauma may, after a free interval of days or weeks, be an important cause of allegedly spontaneous ruptures. In severe P. *vivax* as well as in P. *falciparum* malaria the spleen may have infarctions, focal necroses and multiple interstitial and subcapsular hemorrhages, such as occurred in our case, and in nine of the cases with adequate microscopic examinations. In common with Rigdon's hypothesis, our sections illustrate how reticular and endothelial hyperplasia obstructs venules and sinuses and causes the interstitial and subcapsular hemorrhages. Subcapsular bleeding continues, strips away the capsule over a larger area, and results in further bleeding and distention of the capsule, which ultimately bursts.

The underlying pathology of the paretic spleen may partially explain the higher incidence of splenic rupture in that group of malaria cases. Changes in the fibrous tissue cause loss of elasticity of many paretic spleens.[55, 56]

Lubarsch believes paretics' blood vessels are more friable and, therefore, splenic rupture is more likely.[74] The average duration of active malaria prior to rupture was longer for the paretics than for the normals with malaria, and this might indicate greater resistance or explain the greater incidence of rupture. However, the group is too small to be statistically significant, and the protected life of the inoculation cases would weight the figures in the opposite direction (Table II).

TABLE II

	CNS Syphilis with Malaria	Normals with Malaria
Cases Analyzed	18	20
Average age:	40	29
Number of males	15	18
Number of females	2	2
Number of unstated sex	1	0
Days duration of acute malaria:		
Not stated	1 (12 chills)	3
Not acute	1	3
Less than 7 days	6	10
7-14 days inclusive	2	3
Over 14 days	8	1
Duration of rupture in fatal cases without operation:		
Total	17 studied	4
Less than 3 hours	7	4
3-24 hours	3	All others
24-48 hours	4	operated upon
Over 48 hours	1	
Intermediate	2	

The general increase of tension within the capsule caused by rapid enlargement is probably the most constant etiologic factor in malaria, as well as the other splenic enlargements that rupture. In chronic malaria gradual enlargement may not increase the tension and splenic puncture has been performed in such cases with no immediate ill results.[75] Splenic puncture in rapid enlargements may be disastrous, as we have observed in a case of kala-azar, who died following this procedure.[76] Many of the spleens in this series had multiple deep rents or were fractured completely, suggesting almost an "explosion" of the spleen. Malaria is *par excellence* the cause of rapid splenic hyperplasia and, therefore, the most frequent cause of spontaneous rupture. Ask-Upmark[73] believes reflex spasm of the splenic vein may cause acute congestion and play a rôle in some nonmalarial cases of spontaneous rupture.

The influence of increased intra-abdominal pressure caused by muscular contraction seems significant in some cases. Allegedly normal spleens, as well as a malarial spleen in our present series, have ruptured during labor.[8] Vomiting due to intestinal obstruction may have been an etiologic feature in one case.[39] Vomiting was a prominent feature of the illness prior to rupture in nine additional cases, including ours.[1, 3, 6, 11, 14, 33, 34] Diarrhea occurred in one,[23] and in two, the onset occurred during defecation,[1, 5] and in one case

while pushing a wheelbarrow.[15] Delirium and restlessness were noted in six cases, and all but one of these were paretic.

The relative importance of each of these three factors is difficult to assay. From evidence at hand, all three factors are seldom operative in any single case and the series is too small for any but the most general conclusions about pathogenesis.

CLINICAL FEATURES OF SPONTANEOUS RUPTURE OF MALARIAL SPLEEN

The signs and symptoms recorded in 38 cases in fair detail have been tabulated and are the source of the following data. Miscellaneous symptoms of associated acute or chronic malaria were overshadowed by the dramatic rupture of the spleen.

The clinical features of the rupture were somewhat different in the inoculated cases than in the nonluetic persons. The luetics were older by a decade, and all but one had acute malaria, and usually died less than two hours after onset. Another contrasting feature is that over half of the syphilitics, including six who survived over two hours, and in whom fairly complete examinations were made, died with no complaints of pain at any time. The profound shock was usually attributed to some cardiac complication. It is probably because of the lack of pain and the scanty physical findings that the diagnosis was made in no instance, three were operated upon, with erroneous diagnoses,[34] with two survivals.[24, 53] The nonsyphilitics had severe abdominal pain in all but one instance.

The signs and symptoms are chiefly those of (1) circulatory effects of acute blood loss; and (2) local abdominal effects of bleeding and rupture.

The rapid deaths were all caused by severe blood loss and shock. Our patient was pulseless, unconscious, and was resuscitated only by vigorous antishock therapy. Lack of pain in many instances was probably due to the high pain-threshold caused by severe shock.

Cases with fever have higher metabolic requirements, and acute blood loss in these cases causes earlier and more profound shock and anoxia, and even poorer heat dispersal and more rapid death. Because a few temperatures were recorded in the most rapid deaths the occurrence of this vicious cycle cannot be proven in most cases. The survival-time after rupture could not be correlated with the size of the spleen or with body temperature, or with the age of the person. However, the duration of the malaria prior to rupture was greater in the more rapid deaths (Table III).

The onset of the rupture was sudden and clear, except in two cases,[31, 39] and was heralded by pain or collapse. Two of these had no pain at the onset, and the initial episode was probably formation of a large subcapsular hematoma.[27, 28, 32] The later onset of pain and second collapse was probably due to rupture of the capsule and hemoperitoneum.

The pain of splenic rupture is somewhat variable (Table IV). It is usually severe, generalized, and worse in the left or upper abdomen and flank. Two cases[24, 32] had only lower abdominal pain. This has been attributed to the irritation of blood gravitating to the lower abdomen (Manson-Bahr). Pain

TABLE III

SURVIVAL-TIME OF NONOPERATED CASES

	No. of Cases	Average Age and Range	Avg. Size of Spleen and Range	No. of Days Malaria Symptomatic
Survival less than 3 hours:				
Inoculation	7	43 years (30-50)	483 Gm. (350-750)	12 (5-18)
Naturally-acquired	4	28 years (21-33)	417 Gm. (350-453)	3 (2-4)
Survival over 3 hours:				
Inoculation	8	42 years (26-64)	460 Gm. (375-755)	8-4/7 (2-15)

in the left shoulder (Kehr's sign) referred *via* the phrenic nerve occurred in only six cases. Vomiting prior to, or after, rupture is not infrequent, and in two instances the vomitus contained small amounts of blood, probably due to gastritis associated with malarial infection or the treatment.

TABLE IV

PAIN IN SPLENIC RUPTURE

	Normals and Malaria	CNS Syphilis and Malaria
Degree of pain:		
None	0	10
Mild	1	0
Severe	19	8
Site of pain:		
Undescribed	3	0
Generalized	1	3
Left side	7	1
Epigastric	8	1
Lower abdomen	1	1
Left shoulder and abdomen	6	1
Precordium and left anterior chest	0	1

Except for the physical signs of acute blood loss, the chief findings were abdominal. Where time permitted and findings are recorded, the most common finding was generalized abdominal spasm, usually worse in epigastrium, and occasionally worse in, but rarely limited to, the left upper quadrant. Three cases, however, had no spasm whatsoever, although hemoperitoneum was found at operation. In only one case was the spasm described as "board-like." A few cases had slight abdominal distention, occurring late. The sign of Ballance, persistent left flank dullness in all positions and shifting dullness in the right flank, allegedly specific for rupture of the spleen was reported in only one instance.

It is noteworthy that the spleen was palpable in only five cases, and it will be seen from the pathologic data that many of these ruptured spleens would not be readily palpable even without spasm in the left upper quadrant. Findings there, in addition to spasm and tenderness, described earlier, included dullness of the left flank in five cases.

LABORATORY DATA

Malaria films done preoperatively in eight cases were positive in all. White blood counts were done in only three cases. The usual leukocytosis of splenic rupture may be suppressed by the malaria, but in one case of active malaria the white blood count was 11,000. White count in our case was 5,000, with 75 per cent polys.

Hemoglobin preoperatively was low in five cases. Our case, however, had an hemoglobin content of 13 Gr. per cent because hemodilution had not yet occurred.

Urinalysis in one case and in ours was essentially normal. Plain roentgenograms of the abdomen were made in two cases, and except for the finding of a large spleen in one case, no abnormalities were noted.

DIAGNOSIS

The diagnosis was made in only seven cases and suggested in two others. Perforated peptic ulcer was the preoperative diagnosis in four cases. Other diagnoses listed were "ruptured hollow viscus," "intra-abdominal abscess," "intra-abdominal hemorrhage," and "ruptured uterine tumor."

When active malaria is known to be present, the differential diagnosis includes chiefly the medical causes of malarial shock such as "cerebral malaria," and the other forms of overwhelming malarial infection. These cases are usually due to P. *falciparum,* while P. *vivax* malaria is the chief cause of ruptured spleens, and practically the only form encountered among the veterans. Our only other case of malarial shock was a young veteran admitted with P. *vivax* infestation and coma, convulsions, rectal temperature 108° F., and peripheral collapse.

During malaria treatment of central nervous system syphilis and during other active untreated infections, the occurrence of shock usually led to diagnosis of some intercurrent cardiovascular accident. It should suggest the possibility of rupture of the spleen, since localizing abdominal signs or symptoms may be lacking in the moribund patient. Electrocardiography may be the only differential point.

During latent, chronic or prepatent stages of malaria, splenic rupture is not so rapidly fatal, and localizing abdominal signs are more common. The differential diagnosis then includes the usual causes of acute abdominal emergencies, but chiefly perforated peptic ulcer. The shock due to hemorrhage and the shock of peritonitis may be clinically indistinguishable, if hemodilution has not yet occurred. However, the absence of an ulcer history, presence of a normal leukocyte count and plasmodia in the smear, a not exceedingly rigid abdomen, absence of free air under the diaphragm, and physical findings and symptoms pointing to the left upper quadrant are all helpful differential points and insure proper placement of the incision. Preparations for blood and plasma transfusion should be in progress during diagnostic studies.

Other common diseases such as left pyelonephritis, hydronephrosis, or perinephric abscess, or left lower lobe pulmonary disease caused no confusion in this series.

In the presence of known malaria and localizing findings in the left upper quadrant, without shock, the differential diagnosis includes perisplenitis, splenic infarction, and splenic abscess and volvulus of the spleen. Perisplenitis in malaria is probably the result of minor splenic infarctions, which are not uncommon. The clinical features, as manifested in a series of inoculated patients with central nervous syphilis, are discussed by Read, *et al.*[66] Except for the lack of shock and the spontaneous recovery, the history and findings here were perfectly compatible with rupture of the spleen. We believe subcapsular hematomas are usually followed by rupture, and preparations should be made for emergency surgery.

Abscess of the spleen following malaria is an even rarer complication than splenic rupture.[36]

Volvulus of the spleen has been reported in seven cases since 1930,[8, 67, 68] and was once associated with rupture.[68] In all of these malaria was very chronic, the spleen weighed 1,550 to 7,000 Gm., and was frequently noted to be freely movable prior to the torsion. Except in hyperendemic regions, and in patients receiving poor treatment, this complication is practically unknown.

Other causes of atraumatic hemoperitoneum are listed by Reimann and Cowley.[69] They are less remediable, exceedingly rare, and have been diagnosed only at autopsy.

The difficulties of diagnosis of abdominal pain in latent and prepatent P. *vivax* malaria are well-discussed by Most and Hayman,[70] but their statement that "symptoms and signs of splenic rupture are so dramatic and the findings such that the diagnosis is usually made" is not borne out by this review. The presence of plasmodia in a blood smear does not rule out the need for surgery until the possibility of a ruptured spleen is excluded.

TREATMENT

The treatment of rupture of the spleen is always surgical because, although several alleged cases have recovered without operative treatment, this complication is almost always rapidly fatal.

Operative mortality in the eight cases between 1895 and 1920, before the advent of malarial therapy, is summarized in Table V. Comparison shows that the mortality has not been lowered in recent years, despite advances in technics of anesthesia, shock treatment, and splenectomy.

TABLE V

	Inoculation	Naturally Acquired 1920-1946	Naturally Acquired before 1920
Total cases:	36	19	
Correct diagnosis	0	7	
Operations	3	15	8
Postoperative death	1	4	1
General mortality	94.5%	39%	Nonoperated, almost 100%
Operative mortality	33%	26%	12.44%

Importance of early diagnosis is seen from Table VI, where it can be

observed that all the fatalities, and most of the serious postoperative complications, occurred in those operated upon over 48 hours after onset.

TABLE VI

RELATION OF MORTALITY AND DELAY IN DIAGNOSIS

	Fatalities	Survivals	Nonfatal Complications
Total:	5	14	6
Less than 2 hours	0	2	2 (relapse malaria)
2-24 hours	0	8	1 (wound dehiscence)
24-48 hours	0	1	1 (pneumonia) 1 (relapse malaria)
Over 48 hours	4	2	1 (pneumonia) 1 (subphrenic abscess)
Unstated	1	1	

One case died three hours postoperatively of shock. One case died 16 days postoperatively of pneumonia. Another died of continued hemorrhage, and peritonitis, 12 days after an attempt at tamponade.[16]

Other older methods of treatment, such as suture and enveloping the spleen in omentum, have occasionally been used successfully, but the treatment was splenectomy in every survival in this series.

Generous blood transfusion has been used only in the more recently reported cases, and is essential because of the preëxisting anemia and high fever. Autotransfusion in traumatic rupture of malarial spleens has been used with good results.[71] Paracentesis as a method of diagnosis and preoperative autotransfusion has been used and may occasionally be feasible.[72] Prompt plasma or, preferably, blood transfusion may resuscitate moribund patients, such as ours, and enable diagnosis and operative intervention.

Adequate medical treatment of the associated malaria is essential. Intramuscular atabrine 0.4 Gm. reaches an effective plasma concentration within 15 minutes, which is maintained by 0.2 Gm. i.m. each four hours for six doses, and 0.1 Gm. i.m. or p.o. daily for seven days. This will promptly arrest, or prevent, relapse which, even if not present, is so likely to occur postoperatively. Intravenous quinine must be given slowly, and is more toxic to an already strained cardiovascular system. It offers no advantages over the atabrine treatment outlined.

Although better medical and antishock treatment may improve the surgical mortality, the death of two-thirds of the cases without operation indicates that the greatest need is for accurate and early diagnosis.

CONCLUSIONS

1. The 65th case of spontaneous rupture of a malarial spleen reported since 1917 is described and the other cases reviewed.

2. Spontaneous rupture of the spleen occurs with all species strains and in all stages of malaria, but chiefly in active "benign" tertian (P. *vivax*).

3. The clinical picture, diagnosis and mortality of spontaneous splenic rupture in paretics is contrasted with that during malaria occurring in normals. In paretics, sudden "malarial shock" and peripheral collapse may be due to spontaneous rupture of the spleen even when the patient complains of no

pain, is afebrile, and the abdominal findings are negative. The clinical picture in nonsyphilitics is more typical of findings noted in traumatic rupture of the spleen. However, the abdominal pain is variable; the spleen is usually not palpable; abdominal spasm is moderate; so that the diagnosis was seldom made early, or preoperatively, in this series.

4. Pathologic findings in our case illustrate how reticular and endothelial hyperplasia obstructs venules and sinuses and causes the interstitial and subcapsular hemorrhages that frequently lead to rupture.

5. Treatment of choice is urgent splenectomy. However, energetic chemotherapy of active malaria is vital. Circulatory adjustments to preëxisting anemia, fever and active infection demand prompt restoration of blood volume.

6. With earlier diognosis, blood transfusion and antishock treatment more cases will be operable, and the present high mortality lowered.

Addendum: Photomicrographs were kindly photographed by Dr. Stanley L. Rea, of the Department of Pathology of Tulane University Medical School, New Orleans, Louisiana.

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PENETRATING WOUNDS OF THE CEREBRAL VENTRICLES*

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IN 1918, Cushing[1] reported a series of 30 cases of wounds of the ventricle, with six recoveries. He stated that "one of the most serious complications of penetrating brain wounds is the opening of the ventricle or the traversing of the ventricle by a missile or by bone fragments." Autopsy reports showed that 48 per cent of his patients died of infection; 26 per cent died from hemorrhage either subdural, intracortical or intraventricular; and the remaining 26 per cent died from either extensive intracranial damage or pneumonia. All these cases were débrided without widely opening the dura and by the method of blindly irrigating the tract of the missile. The average time-interval between injury and operation in Cushing's series was 25 hours, with extremes being five and 72 hours.

Haynes[2] has recently reported a series of 100 cases of ventricular injury. In 77 operated cases, the mortality was 33.7 per cent, with 10.3 per cent incidence of infection. He classified penetrating wounds by the size of the missile and damage incurred. Wounds with narrow tracts, produced by small missiles, he treated "by blind suction and irrigation through either the brain needle or long glass aspirator until the ventricle is reached."

This report is based upon 50 consecutive cases of verified ventricular penetration proved by inspection of the opening into the ventricle either at operation or at postmortem examination (Table I). Thirteen (26 per cent) of these cases were operated upon primarily by us at the 21st General Hospital (U. S. Army). There was no selection of cases, and surgery was not denied because of moribund condition. One patient died before operation, 24 hours after he was wounded.

Thirty-one cases (62 per cent) were inadequately débrided at forward installations and were reoperated by us one or more times because of infection or retained foreign bodies. Fourteen (28 per cent) of these had retained bone chips or metallic foreign bodies lying within the ventricle which required removal. There were five proved cases of ventricular penetration which were operated upon at other installations with recovery. Over-all mortality rate was 30 per cent (15 cases), of which 60 per cent was due to infection, and 40 per cent to vital brain damage.

Only two cases returned to combat duty, their reassignment being dictated by the gravity of the tactical situation at the time:

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CASE REPORTS

Case 1.—A 25-year-old French-Arab soldier was wounded on May 13, 1944. He was admitted to our hospital 18 hours after injury, in stupor, with a penetrating wound of the right temporal region. Roentgenograms demonstrated a 3-cm. bone defect, with a shower of bone fragments and two small metallic fragments deep in the *right* parietal lobe and a metallic fragment in the *left* parietal lobe just beyond the midline. At operation, after retraction of the right temporal muscle, a mass of necrotic brain and clot

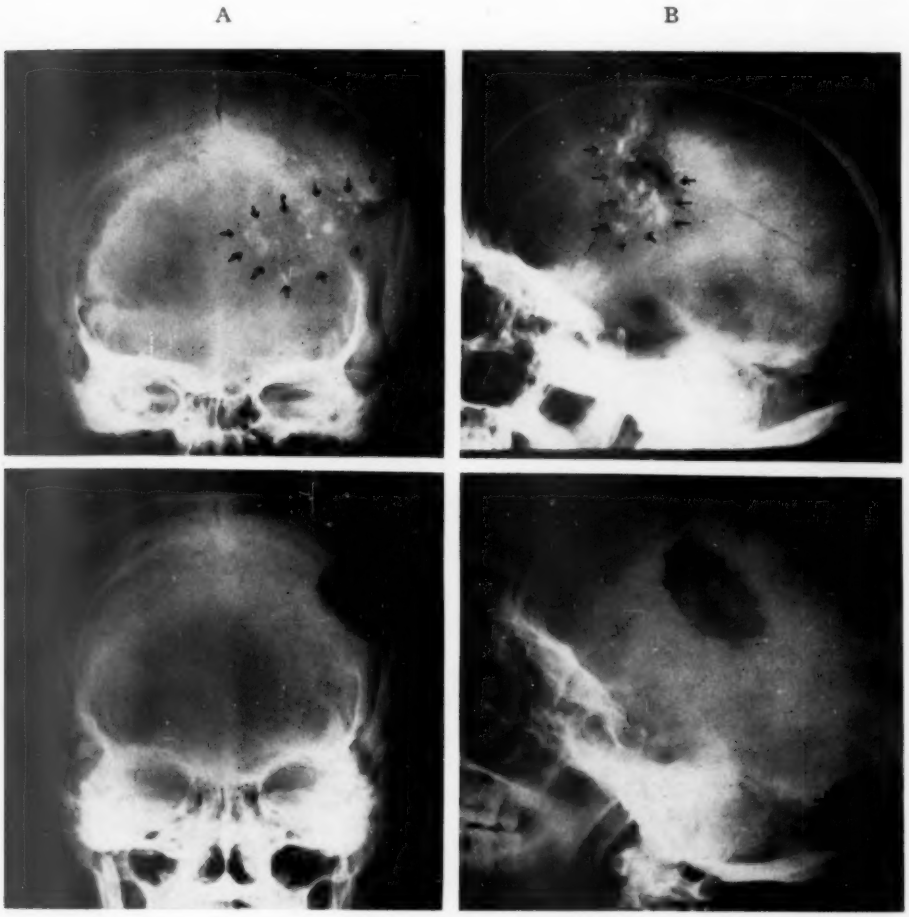

FIG. 1.—Case 2: (a) and (b)—Postero-anterior and lateral roentgenograms showing a penetrating wound in the left parietal bone, with numerous indriven bone fragments, which extended through the anterior horn to the falx.
(c) and (d)—Roentgenograms made after operation. Patient had temporary aphasia and hemiparesis of right arm. Returned to duty 26 days after injury.

gushed out through a 1.5-cm. dural defect. Retractors were inserted into the tract and all damaged brain and bone chips were removed. The tract traversed the body of the right ventricle and one group of bone fragments was removed from the ventricle. The tract was followed for a depth of 7 cm.; there was no indication to go through to the

opposite side to remove the metallic foreign body in the left parietal lobe. As débridement was carried out, the hitherto pulseless brain began to pulsate freely. After operation, the patient had temporary weakness of the left arm and face, and had low grade pneumonia. He improved rapidly, getting up on the 9th day. Paresis of the arm and face cleared completely within two weeks. Because of the tactical situation, and the soldier's great desire to return to his regiment, he was sent back to combat duty on June 1, 1944.

Case 2.—An Arab who was admitted January 30, 1944, 48 hours after injury. He had a tangential left fronto-parietal wound, and showed weakness of the right arm and face and aphasia. Operation consisted of débridement with removal of 15 indriven bone fragments (Fig. 1). The tract extended into the anterior horn of the left ventricle, and the falx was visualized at the end of the tract. Tight closure was effected after mobilization of the scalp and use of a modified Isle of Man incision. The wound healed *per primam*. Within 48 hours, sensory aphasia disappeared. Right arm weakness persisted for two weeks, when motor speech returned. He returned to duty on February 25, 1944.

TABLE I

ANALYSIS OF 50 CASES OF PROVED VENTRICULAR PENETRATION

	Total	Infection	Deaths	Death Due to Infection	Death Due to Brain Damage
Primary operation	13	2	4	0	4
at 21st G.H.	(+1)		(+1 Pre-op)		(+1)
Primary operation Forward	36	31	10	9	1

TIME INTERVAL (HOURS) PRIOR TO SURGERY

	Minimum	Maximum	Average
Primary at 21st G. H.	5	96	39
Primary at Forward Hospital	3	29	15

CASES PRIMARILY DÉBRIDED

There were 13 cases which were operated upon primarily by us (Table I). They were admitted to the hospital at intervals varying from three to 96 hours after wounding, with half the cases arriving within 24 hours after being hit. The average time-interval between injury and operation was 39 hours. Of the 13, there were four deaths (30 per cent). The time intervals between injury and operation in these cases were 12, 23, 31 and 36 hours, respectively. Necropsy demonstrated that death was attributable to damage to vital centers.

There were no deaths from infection, and there were only two cases in which infection developed. One in which the scalp was closed under too great tension developed an abscess in the tract; in the other an abscess formed around a metallic foreign body and leaked into the ventricle. Both cleared up promptly after adequate surgery. Details of these two cases follow:

Case 3.—A 29-year-old soldier, was struck in the right parietal region by a mortar shell fragment, on November 14, 1944. On admission to the 21st General Hospital, 17 hours later, he was comatose. The left side was spastic and there were bilateral pathologic toe signs. Through a 3-cm. wound in the right parietal region, brain and clot protruded. Roentgenograms showed a fracture in the right parietal bone, with multiple indriven bone chips; in addition there was a large metallic foreign body in the midline at the level of the lateral sinus (Fig. 2).

Operation was performed 18 hours after injury. The right parietal wound was débrided. Under direct vision, a forked tract of necrotic brain, clot and bone fragments was followed through the posterior part of the right lateral ventricle, through the occipital lobe, to the tentorium. Through a hole in the tentorium, necrotic cerebellar tissue exuded, and there was considerable bleeding coming from the posterior fossa. A suboccipital craniotomy was then done. Macerated anterior lobe of the right cerebellum

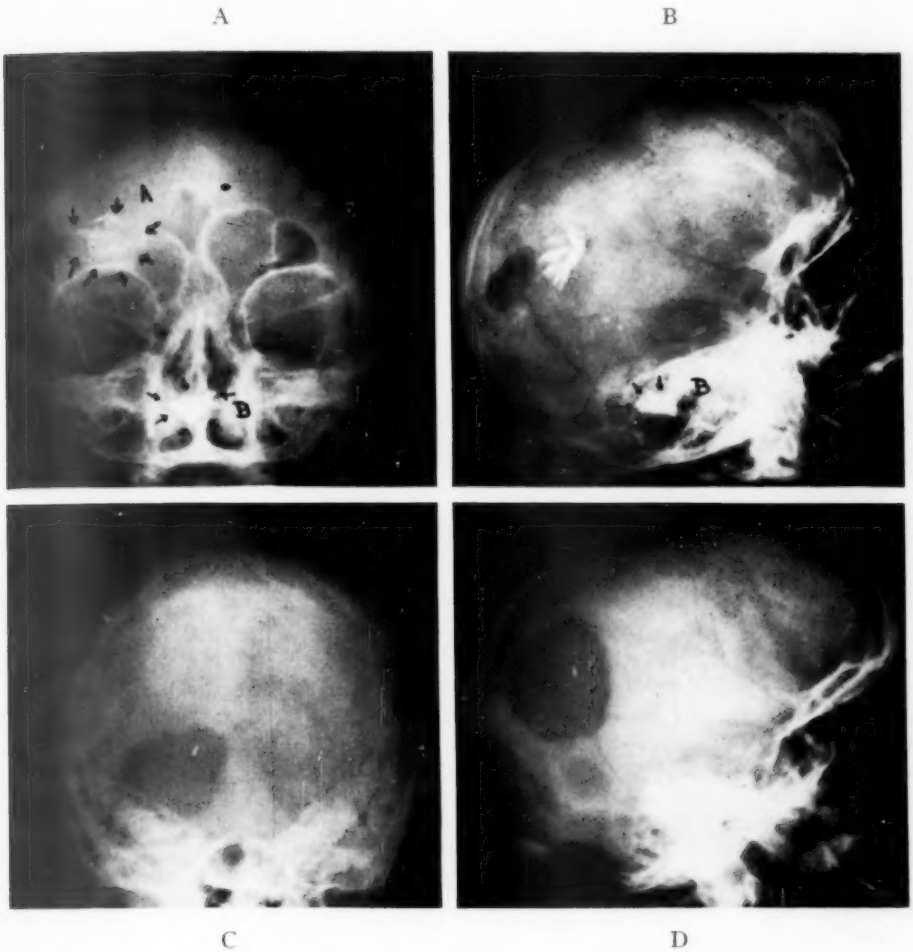

FIG. 2.—Case 3: (a) and (b)—Preoperative films, showing wound of entry in right parietal bone. Bone fragments driven deeply into the parietal lobe (arrows labeled A). A large metallic fragment is present in the midline beneath the tentorium (arrows labeled B).

(c) and (d)—Postoperative films showing parietal and occipital bone defects; bone fragments and metallic foreign body have been removed.

was sucked away. There was a tract leading from the hole in the tentorium to the rostral part of the vermis. Just caudal to the aqueduct, the metallic foreign body was found, directly in the midline, and was removed. Both wounds were closed tightly. Because of loss of skin in the parietal region, a scalp flap was fashioned and rotated to effect closure. By undermining further anteriorly, it was possible to close the donor site

as well. This proved to be an error, since it resulted in too much tension on the suture line. Chemotherapy was begun immediately.

Following operation, the patient's condition improved and he began to respond. The cerebellar incision healed *per primam*. The parietal wound, however, became macerated at its central portion, because of too great tension at the suture line. Aspiration beneath the skin flap showed slightly purulent fluid, examination of which showed numerous pus cells, and gram-positive rods which were thought to be B. *subtilis* after culture. Penicillin was injected locally. Six days after operation, the patient's condition deteriorated. His neck became stiff, and a frank cerebrospinal fluid leak was present through the parietal wound. Skin edges were spread and penicillin was injected through the opening, using 10,000 units every six hours. Two days later, with evidence of an increasing infection, secondary craniotomy was done. The infected tract was sucked out and the ventricle wall was found to be covered with exudate. This was removed. A pocket of foul-smelling pus communicating with the ventricle was evacuated. Penicillin was instilled and the wound was closed. This time, the donor area of the rotation flap was not sutured; thus, good closure over the wound was obtained without tension.

Five days after secondary craniotomy, the donor area was covered with a full-thickness skin graft. The wound healed without further difficulty. The patient's subsequent course showed steady improvement, complicated only by left otitis media and laryngeal diphtheria. The latter complications necessitated delay in evacuation. He was evacuated, February 7, 1945, two and one-half months after his last operation. Examination at that time showed considerable *witzelsucht*, left homonymous hemianopsia, bilateral mystagmus, marked ataxia of the right arm and leg, and staggering gait.

Case 4.—A 21-year-old officer, was struck by mine fragments on May 15, 1944. Evacuation was delayed, and no definitive treatment was given. On admission, May 19, 1944, he was drowsy and the neck was very rigid. There was marked papilledema on the left. The right eyelids were swollen shut. There was an extensive area of contusion and laceration of the right frontotemporal region. The left arm was weak. There was an undébrided wound of the left foot.

Roentgenograms (Fig. 3) showed a fracture of the right orbital ridge and a defect at the sphenosquamosal suture line. There were several small metallic fragments in the right temporal region, one larger fragment just anterior to the right mastoid, and another piece of metal in the occipitoparietal region near the midline.

Operation was performed on May 19, 1944. A defect in the right orbit was found and débrided down through a tear in the orbital capsule. This defect did not extend intracranially. After retracting the temporal muscle, a defect in the anterior part of the squamous bone, just above the zygoma, was visualized. This was enlarged and retractors were inserted into the mouth of a tract which ran posteriorly and medially. Necrotic brain and clot were sucked out. The tract was followed into the temporal horn of the ventricle. The opposite wall of the ventricle was visualized and found to be bruised by the course of one of the fragments. No attempt was made to go beyond the far wall of the ventricle, nor to remove the fragment in the occipitoparietal region. After hemostasis was secured, the wound was closed tightly.

The patient was placed on sulfadiazine, and he began to improve. A mild otitis media developed on the right, which cleared up after removal of the large metallic fragment from the posterosuperior portion of the auditory canal. The head wound healed well, but on the fifth day the patient began to complain of severe headache, and the temporal defect became tense.

On May 24, 1944, the wound of entry was reopened. The tract leading to the ventricle was found to be grossly clean (smears and cultures subsequently reported negative). Accordingly, this wound was closed. A perforator opening was then made in the right parieto-occipital region at a point thought to be near the retained foreign body. At a depth of 3 cm., an abscess was found and very foul pus was aspirated. Gram-positive rods were seen on smear.

Roentgenologic examination was repeated, for better localization of the foreign body, and two days later, the fragment was removed. It lay in a pocket containing a small amount of pus and was surrounded by necrotic brain. The perforator opening was closed.

The patient again did well for about five days, but then began to get drowsy, and

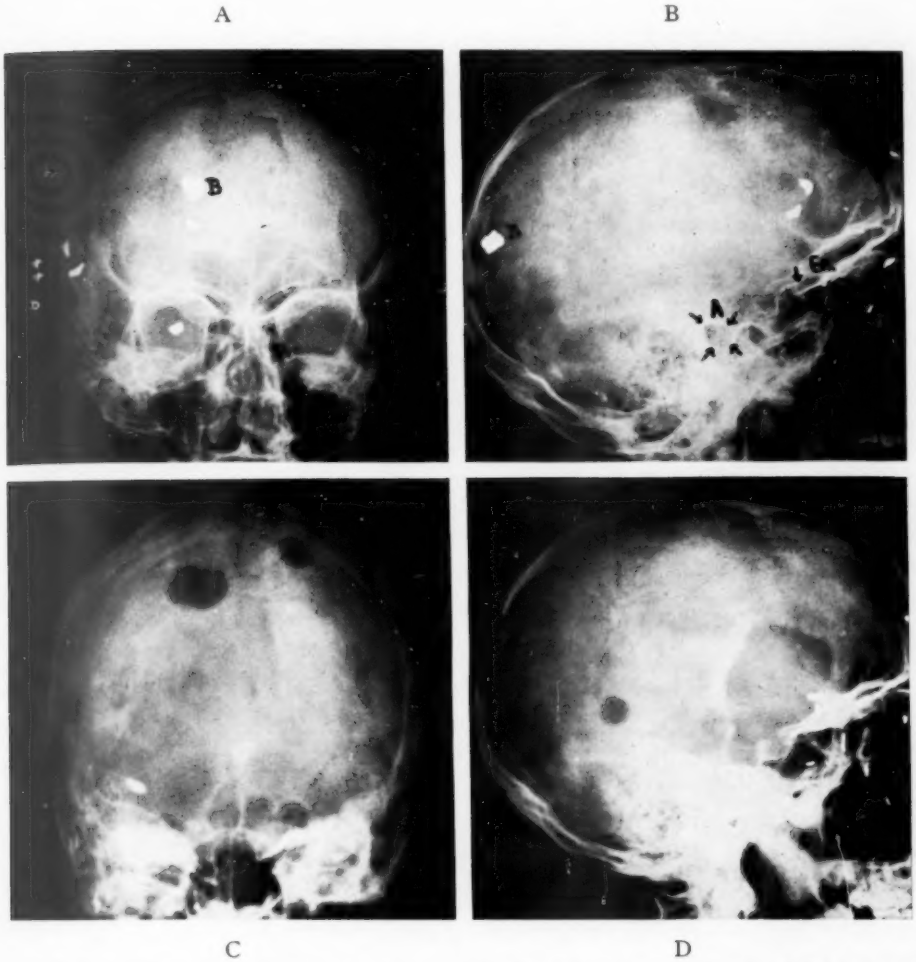

FIG. 3.—Case 4: (a) and (b)—Preoperative films showing entry wound, frontotemporal (EN. and arrows); numerous small metallic fragments, one large fragment (A and arrows) just anterior to the right mastoid; one fragment (B) in the parieto-occipital region near the midline. The latter was found to be associated with a *Clostridial* abscess which communicated with the ventricle and was removed at a second stage.

(c) and (d)—Final postoperative films before discharge, showing the temporal bone defect; the metallic fragments in the right parieto-occipital and mastoid regions have been removed.

showed evident signs of increased pressure. On May 31, 1944, following ventriculography, the right occipitoparietal bur-hole was reopened, and a large quantity of pus gushed out. Through the previously-created dural defect, retractors were inserted and a tract sucked out. The walls of the tract were covered with thick exudate, and the tract was found to communicate with the lateral ventricle. After evacuation of the tract, 10,000 units of

penicillin were instilled. The wound was closed with silk, leaving a narrow corrugated rubber drain, which was removed after two days. (This was contrary to our usual practice, but at this time, we were still fearful of *Clostridial* infection). Bacteriologic examination showed the organism to be C. *sporogenes*. After removal of the drain the wound was completely healed in ten days.

Following this operation, the patient's course was very satisfactory. Convalescence was delayed by the wound of his left foot. This was closed secondarily on June 18, and the patient was then allowed to get up. Examination showed a temporal field defect in the left eye with central field intact. Vision in the right eye was limited to light perception, due to detachment of the retina and vitreous hemorrhage. Hearing on the right was 6/20; on the left 20/20. There was slight weakness of the left arm, but fine hand movements were present.

He was evacuated on July 14, 1944. Letters were received at frequent intervals. There has been no recrudescence of infection as late as 20 months after operation. Vision has improved to the point where this man is able to play as excellent a game of golf as before his injury, and he leads his customary active life on his farm.

CASES PRIMARILY OPERATED UPON IN FORWARD INSTALLATIONS

Of 36 such cases which reached our hospital, 31 required secondary operation. Primary operations were performed at intervals ranging from three to 29 hours after injury, with an average time-interval of 15 hours. Among the 31 there were 12 cases of abscess, three of meningitis, and 14 cases of ventriculitis and meningitis; there were two cases with retained bone chips without clinical evidence of infection. There were ten deaths in this group of cases (32 per cent), with infection being the responsible cause in nine (Table I).

FACTORS IN MORTALITY

Analysis of our own cases as well of those of others, reveals that there are three factors which are of paramount importance in the production of the morbidity and mortality following wounds of this type.

I. *First is introduction of infection, with resultant ventriculitis.* This is one of the most feared complications of ventricular penetration, and is borne out in our cases. Treatment should, therefore, be directed towards removal of the potential source of infection and eradication of infection if already present.

Case 5.—A 26-year-old soldier, was wounded in the left frontal region by a shall fragment, on March 5, 1944. Craniotomy was performed 24 hours later at an Evacuation Hospital; a 7-cm. tract was cleaned out, sulfanilamide was instilled, and the wound was closed, with a drain. Chemotherapy was instituted. On removal of the drain on the following day, leakage of cerebrospinal fluid was noted.

On admission to the 21st General Hospital, March 11, 1944, there was a defect in the lower part of the wound, with sanguinopurulent drainage. On compression of the upper part of the wound, gas escaped through the defect. Cultures of the pus were reported positive for staphylococcus and streptococcus. Roentgenograms (Fig. 4 a, b) revealed a large frontal defect, involving the supra-orbital ridge and left frontal sinus, with extensive linear fracture lines. There was a large nest of retained bone fragments in the left frontal region, in a position corresponding to the anterior horn of the ventricle. Lumbar puncture revealed elevated pressure (310 mm. of water); the fluid was cloudy and contained 250 cells.

On March 14, 1944, secondary operation was performed. A mass of pus and

necrotic brain was found and removed. Retractors were inserted through a tract 8 cm. long and 1.5 cm. wide, which led directly to the anterior part of the lateral ventricle. Four bone chips were removed from the depths of the tract. The wound was closed. There was steady improvement for five days, at which time the lower end of the wound

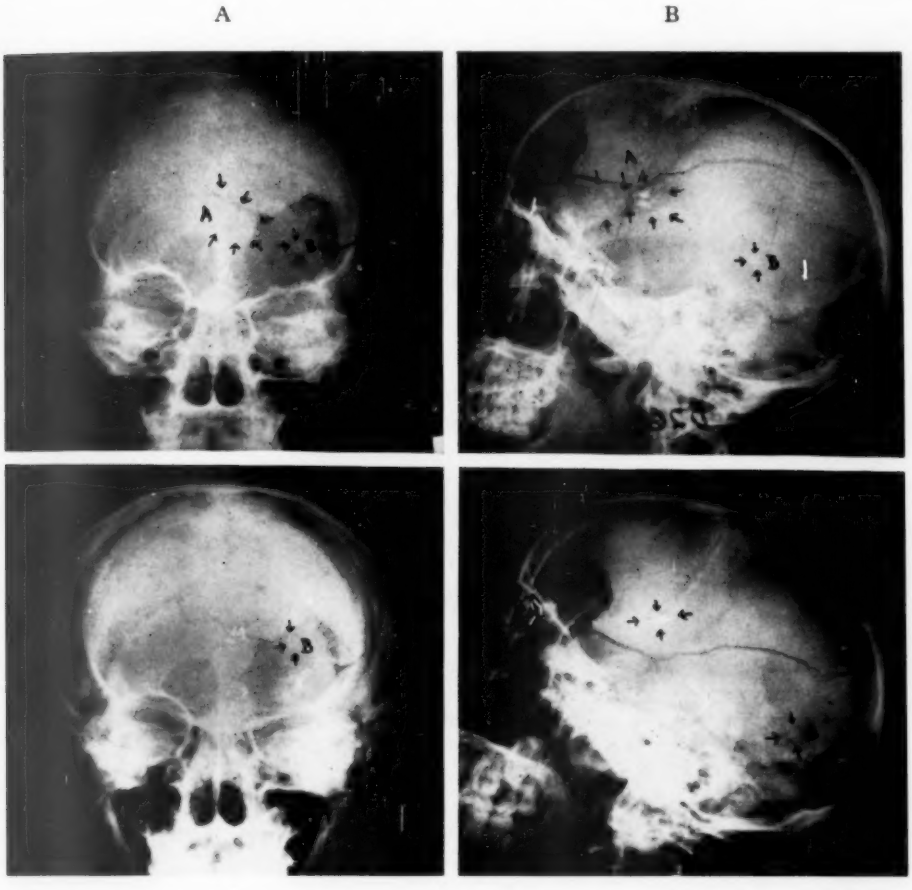

FIG. 4.—Case 5: (a) and (b)—Roentgenograms on admission, prior to secondary débridement. There is a large frontal bone defect, with numerous retained bone fragments (A and arrows) driven in to the anterior horn of the ventricle. The barely perceptible fragment outlined by arrows and labeled B was overlooked.

(c) and (d)—Postoperative films show the large nest of bone fragments in the frontal lobe replaced with silver clips. The small fragment (B) which was overlooked in the preoperative films, has shifted position and now lies in the occipital horn.

was spread, and 10 cc. of pus escaped. Purulent drainage increased and the patient became aphasic. Roentgenograms (Fig. 4 c, d) revealed that the nest of bone chips had been removed. Reoperation revealed an abscess just beyond the limits of the previous exploration.

The patient's course was steadily downhill. Repeated smears and cultures after March 14 showed gram-positive rods. Signs of meningitis progressed. Bilateral postparietal bur-holes were made on April 4, and 10,000 units of penicillin was injected into

each ventricle daily. In addition to parenteral penicillin and sulfadiazine, this patient received 155,000 units of penicillin intraventricularly. He died on May 12, 1944. Autopsy revealed extensive encephalomalacia of the left hemisphere, basal ganglia and thalamus. There was marked left frontal cerebritis and lateral ventriculitis.

On reviewing this case, it is apparent that incomplete débridement, with retention of bone fragments, was responsible for the infection. The lack of available penicillin during the first days of his hospitalization cannot be blamed. After very careful reëxamination of the roentgenograms, it was found that one barely perceptible bone chip was overlooked in favor of the prominent nest of bone in the anterior horn. In comparing the films before and after removal of this mass, it can be seen that a chip lying in the posterior parietal region was still present and had shifted position (Fig. 4 b, d). This obviously lay in the occipital horn. In view of this finding, we believe that, had we not overlooked this bit of bone, its removal through a separate approach might have resulted in a happier outcome.

Case 6.—A 20-year-old French soldier, received bilateral parieto-occipital wound on November 15, 1944. Twenty-five hours later, operation was performed at an Evacuation Hospital. Because of bleeding from the lateral sinus, débridement was not completed. The wound was packed with gauze. Five days later, without any further attempt at débridement, secondary closure, with a transverse skin relaxing incision, was done.

On admission, November 25, the patient was disoriented. His neck was stiff. There was complete amaurosis. The transverse wound over the occiput was found to be broken down and infected, and the relaxing incision was likewise infected. There were bilateral occipital lobe herniae. Roentgenograms (Fig. 5a, b) revealed numerous indriven bone fragments. Sulfadiazine therapy was instituted and severe cellulitis of the scalp was reduced to some extent with wet dressings.

On November 28, the wound edges were excised and spread. The bone defect was enlarged and the longitudinal sinus exposed. The latter had been completely destroyed for a distance of 2 cm. just anterior to the torcula. Two large bone fragments were removed from its stump and bleeding was controlled. Two tracts in the left occipital fungus were cleaned out to a depth of 3 cm. Because of the overwhelming scalp infection, this procedure was planned solely to remove bone chips and establish adequate external drainage. Therefore, the wound was left open.

There was steady improvement on sulfadiazine therapy until December 9, when high fever and cervical rigidity returned. Penicillin was given intrathecally. Under local treatment, the scalp became much cleaner and another operation was performed on December 16. Just lateral to the left occipital fungus a tract was found which led directly into the occipital horn of the lateral ventricle. After débriding the tract, the body and temporal horn were well-visualized. The ventricular fluid was cloudy and the wall was smooth and glistening. The choroid plexus was coagulated, clipped and excised. It was thought best not to close the dura with a graft at this time. A single-pedicle scalp flap was mobilized to cover a 12 x 4 cm. defect, and the scalp was closed after instilling 10,000 units of penicillin into the ventricle.

Signs of meningitis persisted, despite daily intrathecal injection of 20,000 units of penicillin. Spinal fluid cultures were consistently positive for *Staphylococcus albus*. On December 28, the patient became worse. Lumbar puncture did not affect the tension of the occipital defect. Right ventricle puncture through an anterior bur-hole readily decompressed the defect however. It was evident, therefore, that a block existed at the aqueduct, or below. Penicillin was injected into the ventricle daily. By January 6, the

block had disappeared and the patient was greatly improved, but large amounts of fluid continued to collect beneath the scalp defect. On January 16, the wound was reopened. The porencephalic cavity in the left occipital lobe measured 60 cc., and there was an 8-mm. opening into the occipital horn (Fig. 5c, d). The tract was clean except for a small amount of exudate at the opening into the ventricle. The dura was closed tightly with a fascia lata transplant, and the scalp was closed in layers with silk.

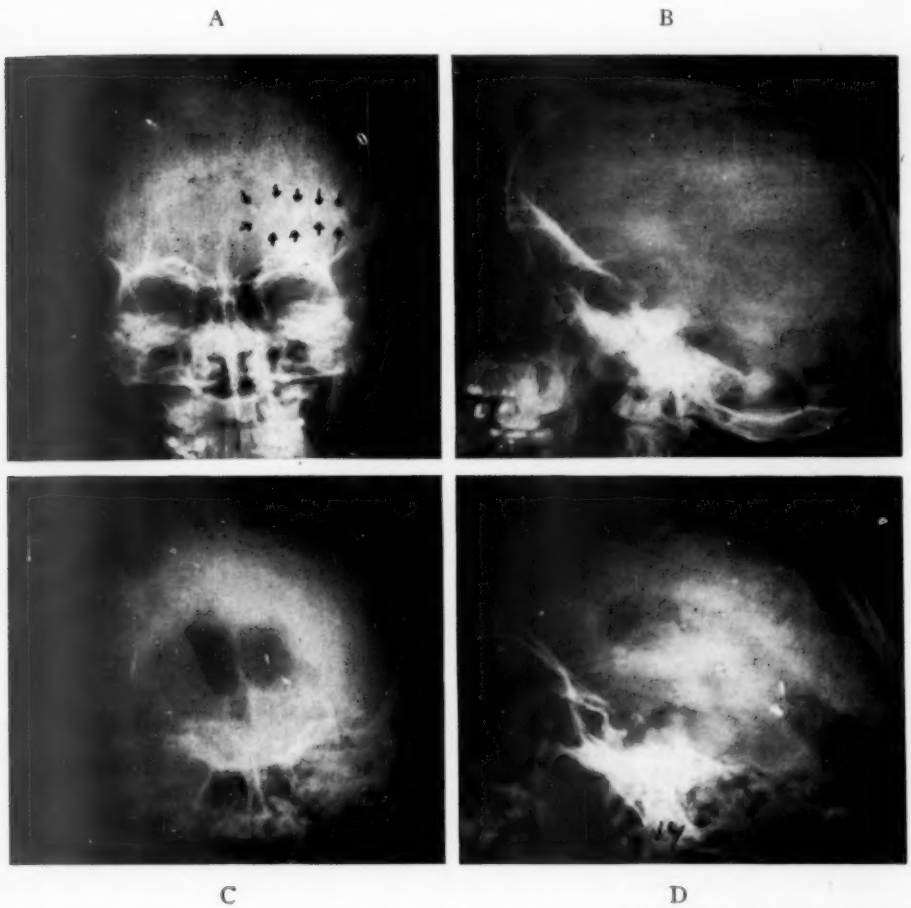

FIG. 5.—Case 6: (a) and (b)—Films before secondary débridement, showing numerous indriven bone fragments and entry wound (EN).
(c) and (d)—Ventriculograms after débridement of tract which communicated freely with the left occipital horn; at débridement, the left choroid plexus was removed. Films show air in the occipital tract and air in the ventricles; silver clips are seen at point of communication between porencephalic occipital lobe and the left ventricle.

Following this last operative procedure, the patient showed steady improvement, interrupted, however, by repeated flare-ups of staphylococcus meningitis. These responded to penicillin therapy, and fluid remained clear after February 10. He became able to get about, and there was light perception in both eyes. The wound was solidly healed. When the patient was evacuated to a French Hospital on March 7, neurologic examination was negative, except for visual loss.

II. *The second factor, or complication, is that of hemorrhage into the ventricular system.* Aggressive efforts must be made to arrest or prevent hemorrhage and to remove as much blood and clot from the ventricles as possible.

We have relegated ventricular hemorrhage to a position of less importance than that of infection because in our series of cases of penetrating ventricular wounds varying in time after injury from a few hours to several days, ventricular hemorrhage was by no means as frequent a complication as was infection. The probable reason for this is that these cases died soon after injury and never got back to us. The fact that there were so few such cases in our series, in no way lessens the importance of this complication or in any way modifies the recommendation that the clot should be removed from the ventricle under direct vision.

Case 7.—A 27-year-old soldier received a penetrating wound in the right midparietal region, on December 22, 1944. He had immediate paralysis of the left arm and leg, but was able to talk on admission to an Evacuation Hospital, where operation was performed 26 hours after injury. The surgeon noted that 200 cc. of clot and pulpefied brain were removed along with bone spicules. After instilling 50,000 units of penicillin, the wound was closed. Meningitis developed in six days, and treatment with intrathecal penicillin was instituted.

On admission to the 21st General Hospital on January 5, 1945, the patient was aphasic. There was complete left hemiplegia with loss of fine discriminatory and position sense on the left. There was bilateral papilledema. The wound was broken down and infected over an area 3 cm. long near its center. Roentgenograms showed several large bone fragments, deep in the parietal lobe, with one fragment shifting in position (Fig. 6 b, c).

On January 7, 1945, secondary craniotomy was performed. After excising the infected scalp, and removing the dural graft, the mouth of a tract was found in protruding brain. Retractors were inserted into the tract and a large mass of old clot and necrotic brain was evacuated. The resulting cavity was 60 cc. in volume and communicated, at a depth of 5 cm. with a very large defect in the superolateral wall of the right lateral ventricle. The ventricle was very large and distended with an organized clot. On removal of the clot, the entire body of the ventricle was visualized, and explored through the large opening in its wall. Four bone fragments were found lying in the ventricle. One sizable bone fragment was found adjacent to the foramen of Monro. It was thought that the dilatation of the ventricle was the result of the large clot rather than blockage of the foramen by the bone chip. After instillation of 20,000 units of penicillin, the dura was closed with a fascial transplant. The scalp was closed by means of a rotation flap, and the donor area was covered with a full-thickness skin graft.

The wound healed *per primam*, and the patient improved steadily, with rapid clearing of papilledema. Postoperative roentgenograms, however, revealed one retained bone fragment which shifted in position between the temporal horn and body of the ventricle (Fig. 6 d). Since cultures made at our first operation were positive, it was decided to reoperate and remove the remaining fragment. After a short delay, due to the patient contracting laryngeal diphtheria, this was done on January 20, through a temporal approach.

All wounds healed promptly. Aphasia began to clear within a week, at which time the patient informed us that he had been left-handed as a child. About one month after our first operation, the parietal wound became puffy at one point; this was opened and a small cotton pledget was removed from beneath the galea. No further complications occurred. He was evacuated on March 21, 1945. At that time, eye grounds were normal.

There was left homonymous hemianopsia. Speech was improved, but by no means normal. The left arm was still paralyzed; considerable power had returned in the left thigh.

III. *The third factor, that of associated damage to vital centers,* is the least amenable of all to improved therapy. A fairly large percentage of deaths

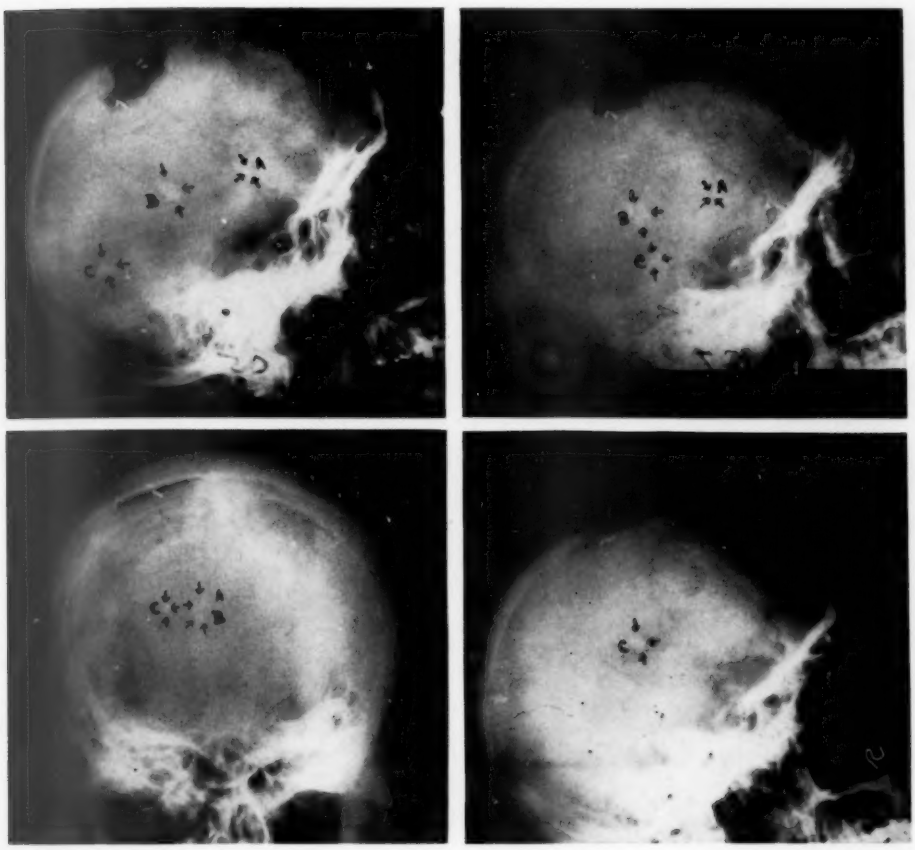

FIG. 6.—Case 7: (a) and (b)—Lateral views, prior to secondary débridement, showing three groups of bone fragments; A lies at the foramen of Monro; B lies in the body of the ventricle; and C is shown shifting in position from the occipital horn to the temporal horn.

(c)—Anteroposterior view. At operation, a large clot was found filling the body of the ventricle.

(d)—Lateral film, after secondary débridement. Compare with (a) and (b). The fragment which was originally visualized in the temporal and occipital horns, is retained and can be shifted into the body of the ventricle. Bone fragments labeled A and B in the preoperative films have been removed, together with intraventricular clot.

from this cause was expected and most series of cases will bear this out. However, since many patients with vital center damage did not live sufficiently long to allow for operation, they formed only a modest group among our cases.

That some such cases may survive long enough to undergo extensive surgery, only to expire days, or even weeks later, must be recognized. This is exemplified by the following case, in which the patient withstood the effects of intraventricular hemorrhage, but succumbed to a lesion of the brain stem.

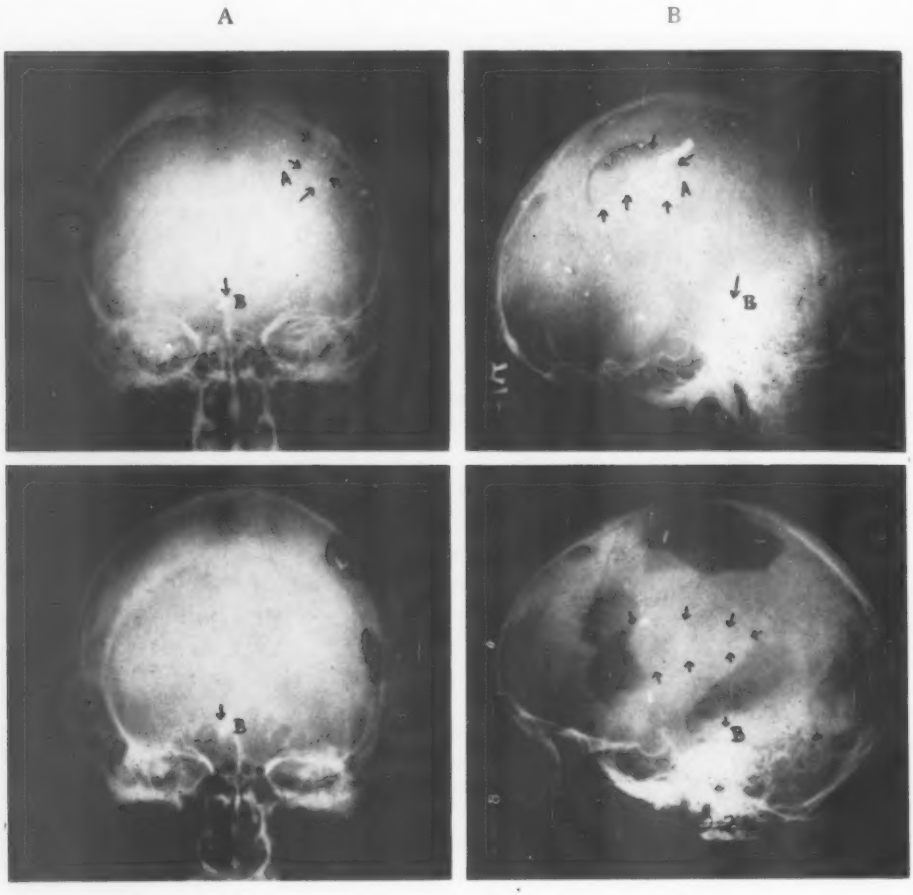

FIG. 7.—Case 8: (a) and (b)—Original preoperative films showing a large metallic fragment and indriven bone chips (A) and a small metallic fragment (B) in the brain stem.

(c)—Postero-anterior view after débridement, showing two defects in the left frontal and parietal bones, and retained metallic fragment in the brain stem.

(d)—Lateral ventriculogram, showing anterior and temporal horns of left lateral ventricle; arrows outline a large defect in the body of the ventricle, corresponding to intraventricular clot.

Case 8.—A 23-year-old soldier suffered left frontal and parietal penetrating wounds on May 31, 1944 (Fig. 7 a, b). He became unconscious immediately and remained comatose. At an Evacuation Hospital, débridement was performed within 24 hours after injury. The patient's condition became so bad that complete operation had to be abandoned. The scalp was closed.

The patient remained in coma. He was transferred to the 21st General Hospital on June 4, 1944. There was a 6-cm. left frontal and a 20-cm. left parietal sutured scalp wound. Both wounds were tense and did not pulsate. Roentgenograms showed the underlying bone defects, with two small bone chips in the parietal lobe, and a metallic fragment in the midline near the base (Fig. 7 c). After removal of the skin sutures, the scalp wounds began to gape, and the parietal wound broke down with discharge of foul pus.

On June 7, 1944, the parietal wound was opened widely. The purulent cerebral hernia was amputated and a necrotic tract was followed for 3 cm. The brain remained very tense. A ventricle needle was introduced and a large quantity of clot and old blood was aspirated from the ventricle. The brain began to pulsate. Because of the patient's continued poor condition, it was thought unwise to explore the ventricle under direct vision, but to attempt to tide him over with ventricle punctures. Cultures showed staphylococcus on both aerobic and anaerobic media.

The patient's condition remained poor, and he again showed evidence of pressure. On June 10, 1944, ventricle puncture was done, and 40 cc. of old, brown blood mixed with clot was obtained. Since the brain was still tense, it was felt that a good deal of clot was still present and further ventricular aspiration was futile. Ventriculogram (Fig. 7 d) showed a large defect in the dilated left ventricle. It was obvious that, despite the patient's poor condition, removal of the clot was necessary. Accordingly, retractors were introduced down to the ventricle. A large, old clot, surrounded by a thin membrane was found in the dilated ventricle. The membrane was found to be attached at several points to the choroid plexus. Clot and membrane were removed. One large piece of clot, separate from the main mass, was plugging the foramen of Monro. After removal of clot, the walls of the tract through which retractors had been introduced fell away, leaving a cavity 6 cm. deep by 3.5 cm. in width, communicating freely with the dilated left ventricle. Closure was carried out, using fascia lata transplant for the dura.

There was no change in the patient's condition, and he died on June 13. Autopsy showed the tract to be clean; the left ventricle was collapsed and free of clot or exudate. Extending through the substance of the brain on the left side from the mesencephalon into the pons was a hemorrhagic area 1 cm. in diameter and 5 cm. long. The metallic fragment was found lying in the center of a necrotic area 2 cm. in diameter in the very center of the pons.

PATHOLOGY

The pathology of wounds involving the ventricles is the same as that seen with all types of wounds produced by high explosive shell fragments or bullets, and little needs to be added to what has already been written on this subject. There is, first of all, a shattering of the skull, depending upon the size of the missile involved and the angle at which it strikes. The dura is torn jaggedly to an extent which depends on the size and velocity of the missile, the comminution of the skull, and the number of indriven bone chips and foreign bodies. The tract is filled with pulped brain, blood clots, bone and metallic fragments. The opening into the ventricle may be of any size, dependent upon the size of the missile and angle at which it has traversed the ependyma. The ventricle may be filled with bright blood or clot, plus bone chips, hair, *etc.*, or the opening may be only a tiny slit which seals off under pressure of surrounding edematous brain.

With incomplete débridement, if an abscess in the tract develops, it may leak into the ventricle to produce ventriculitis; or if the ventricle itself is not cleaned out, infection may develop primarily within the ventricular system.

Failure to effect hemostasis from a bleeding choroid plexus may produce clots in the entire system or on a single side with a block of the foramen of Monro. Similarly, infection within the ventricles, producing a shaggy exudate over the ependyma and choroid plexus, may extend throughout the system and may lead to foraminal block.

DIAGNOSIS OF VENTRICULAR PENETRATION

We have not been able to diagnose ventricular penetration by symptomatology. Signs are dependent upon the area of the brain involved rather than penetration of the ventricular wall. That these patients are usually acutely and seriously ill is to be expected from the amount of cerebral tissue which must be damaged in order for a missile or bone fragments to reach the depth at which the ventricles lie. On the other hand, a few cases, with a narrow tract of brain damage and little hemorrhage, may present a deceptively excellent general appearance. A diagnosis of ventricular penetration may be suspected when radiographic examination reveals a tract outlined by bone chips leading toward the normal position of the ventricle, but this is by no means certain. Occasionally, one can make a diagnosis with reasonable certainty, when films show a radiopaque foreign body which shifts with movement of the head.

TREATMENT

Treatment of ventricular wounds is no different from that of other penetrating wounds of the brain, even though they are more serious by virtue of the depth of the wound. In a previous paper[3] we have reported our early experiences with primary and delayed treatment of penetrating wounds of the brain, and the actual technic will not be discussed here. As further experience accumulated, radical surgery, with closure, became accepted procedure in almost all cases, despite gross evidence of infection. There are some features of ventricular wounds however about which more should be said.

Routine stereoscopic roentgenograms (anteroposterior and lateral) of the skull are of particular value in cases suspected of ventricular wounds. This will aid in diagnosis not only by giving the dimension of depth to foreign bodies but will also assist in the detection of a shift of a foreign body. Further, accurate visualization of the pattern of a group of bone fragments may confirm suspicion of ventricular penetration.

Patients suspected of having a ventricular wound should be given top priority for surgery, for the greater the delay the greater is the risk of infection or clot in the ventricles. Operation should be performed promptly, preliminary treatment for shock or dehydration having been started as soon as possible.

It should be reëmphasized here that the crux of the treatment of these wounds is adequate, thorough, aggressive débridement of the entire tract including the ventricle, under direct vision. It is not reasonable to assume that adequate débridement of all pulped brain, clot, hair, bone and metal can be done without visualization of this material. Not only will débridement be

inadequate but the danger of producing extensive damage outside the missile tract or of producing further hemorrhage is ever present. In our experience, following the tract has not been difficult, for as the narrow malleable retractors are placed deeper and deeper and pulped brain and clot removed, tension falls rapidly and the tract may be spread easily without doing further damage to the brain.

In late secondary cases, with abscess and ventriculitis, again we believe that radical complete débridement with primary closure is essential. Since one cannot hope to cure a ventriculitis until the source of contamination is removed, the abscess is evacuated under direct vision and the shaggy exudate is thoroughly sucked-off the wall of the tract. Likewise, the ventricle is inspected, and clot and bone fragments are removed. Metallic foreign bodies are removed if readily reached, without inflicting additional trauma. Occasionally, metallic fragments may require removal by drastic means, but in most cases they are innocuous. Penicillin is instilled just prior to closure.

Closure of the dura has been accomplished in almost all our cases by pericranial, temporal fascia or fascia lata grafts, both in early and late secondary cases. Just as in uncomplicated penetrating brain wounds, we have found that the danger of loss of a graft through infection in a thoroughly débrided wound is negligible. On the other hand, the presence of a water-tight dural closure minimizes the danger of a ventricular fistula, should a scalp closed under too much tension give way. Too, if the dura is not closed there is a tendency for ventricular fluid to collect under the widely mobilized scalp, to inhibit galeal-pericranial apposition, and to constantly keep the suture line under tension. If great care is not taken the wound will spread from the tension and a fistula may develop, with disastrous results from infection.

We believe that fresh pericranium or fascia is the material of choice for water-tight closure. Fibrin film was used as a dural substitute in two cases with a widely open ventricle; fluid continued to accumulate beneath the galea, until the film was removed and replaced with fascia.

CHEMOTHERAPY

In World War II there have been two factors which have been instrumental in the marked lowering of morbidity and mortality rates in head wounds. First, is complete débridement; and, second, is chemotherapy. There is no drug which will ever replace complete débridement in penetrating wounds of the brain, and so much drug has been given indiscriminately that it is doubtful whether we shall ever be able to determine accurately the effectiveness of each. That chemotherapy has its place in the treatment of penetrating head wounds in general, and of ventricular wounds in particular, goes without saying. We have used sulfadiazine and penicillin, alone and in various combinations, and both have proved to be effective parenterally.

In penetrating ventricular wounds, we have generally instilled 10,000 to 20,000 units of penicillin into the ventricle before closure. In cases in which signs of ventriculitis are not present, this has sufficed. If, on the other hand, definite ventricular infection was found at operation, penicillin in amounts

from 20,000 to 50,000 units in spinal fluid have been administered daily until all signs of infection disappeared. If there was some contraindication to the lumbar route of administration, as for example internal hydrocephalus, it was injected directly into the ventricles through the bone defect or through perforator openings made especially for this purpose. In our experience, intraventricular injection of penicillin in the presence of infection has resulted in no deleterious effects.

SUMMARY AND CONCLUSIONS

An analysis of 50 proved cases of wounds of the cerebral ventricles is presented. Ventricular penetration was verified by direct inspection at the time of operation or at postmortem examination. There were 15 deaths in the group, including one patient who died before operation.

In a series such as this, in which some of the initial operations were performed under varied circumstances by several different surgeons, statistical analysis means little. However, there are some conclusions which may be accurately drawn.

Of 13 cases operated upon primarily, there were four deaths, all of which were due to brain damage. Of 36 cases which were operated upon at forward hospitals, 31 required reoperation; there were ten deaths in this group, of which nine were due to infection.

Factors in mortality and morbidity have been reviewed, with illustrative case histories. In those cases of ventricular injury which survive long enough to reach surgery, infection is at least as responsible as vital brain damage as a cause of death.

Treatment consisting of prompt and thorough débridement of the entire brain tract including the ventricle may be expected to lower the mortality rate. Such débridement should be carried out under direct vision. Infected cases should be handled in the same way, with removal of débris, retained bone fragments and pus, and closure of the wound.

Direct instillation of penicillin at the time of operation, plus penicillin parenterally, and sulfadiazine are effective only when combined with necessary surgery.

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SOME EFFECTS OF EXPERIMENTAL THERMAL BURNS ON VASCULAR ENDOTHELIUM EMPLOYING A PERFUSION TECHNIC IN ANESTHETIZED DOGS

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THE PROBLEM

CONVENTIONAL METHODS for producing burns in physiologic investigations have been relatively crude insofar as they affect many vital structures simultaneously. For example: Keeley, Gibson and Pijoan[1] applied the flame of a Bunsen burner to the skin of the thorax in anesthetized dogs, and judged the character of their burns by the uniformity of blanching obtained. Underhill, Kapsinow and Fisk[2] applied a heated iron with a fixed temperature to skin surfaces for varying periods of time. Wilson, Jeffrey, Roxburgh and Stewart[3] inserted an active electrode with a flat disk into the subcutis beneath the platysma to burn all components of skin equally. Field, Drinker and White,[4] and others, have immersed the feet of anesthetized experimental animals in water at 100° C. for varying periods of time to create standard reproducible burns. By all these technics the epithelium, nerve endings, nerve fibers, accessory glands with their ducts, loose connective tissue, blood vessels, lymphatics, and subdermal structures are affected unselectively. It is true that a burn, obtained by immersion of a part in hot water at a known temperature for a definite number of seconds, is readily accomplished and easily repeated. Furthermore, this type of burn is directly comparable to human experience in military and in civil life. Yet the fact stands out in the minds of all who have attacked the problem, that such burns and their possible general effects represent different degrees of heat attack upon many different tissues. At the surface, heat coagulation will occur; and destruction of cells — red, white, epithelial, and endothelial—of smooth muscle, of striated muscle, *etc.*, will be accomplished where the heat is greatest, and will grade to the center of the part where no damage may be done. Experimental burns readily simulate human experience, but do not give opportunity to relate burn damage both locally and generally to uniformity of attack upon any tissue in the injured part. Assuming—and it is not an idea unjustified by other experiments—that injury to vascular endothelium may be the most fundamental lesion in burns, it has been the idea behind these experiments that if the leg of an anesthetized dog was suddenly perfused with a hot solution of 6 per cent gum acacia, and after a few minutes of uniform vascular and adjacent injury the perfusion was stopped and the circulation restored to normal, there would be a degree of uniformity in the effects of heat not attainable through surface burning by the

methods which have usually been employed. Certainly, the use of such a technic must first affect the vascular endothelium, and must show to some degree whether injured endothelial cells readily contribute substances to the blood capable of causing dangerous systemic effects.

A method has, therefore, been developed for perfusing the vascular tree of the hind leg of an anesthetized dog with hot solutions, a method permitting return to the normal circulation of the part when the perfusion was ended. It has been possible to observe the local effects and to record the absence of general effects as the immediate results of these burns.

The original idea behind these experiments was that injury produced by hot perfusions might leave the vessels of an extremity specifically damaged, and it would then become possible to make observations on such matters as return to reasonably normal permeability of capillaries, characteristics of contraction and dilatation of vessels on appropriate stimulation, fibrin formation, and other issues in the little explored physiology of blood vessels turning toward normal in inflamed tissue. This field of observation was not reached, but data have been gathered on the immediate effects of these thermal burns on capillary permeability and on the absence of immediate systemic effects from the burns.

EXPERIMENTAL TECHNIC

Mongrel dogs, ranging from 12 to 22 kg. in weight, were used. No preliminary studies as to hydration, nutrition, blood protein levels, or anemia were carried out. Sodium nembutal was administered intravenously for general anesthesia, 32 mg. per kg. being given initially, with supplemental doses to maintain full anesthesia at all times.

The right external carotid artery was cannulated for recording arterial blood pressure. The external jugular vein was exposed for giving intravenous fluids and taking blood samples. A thermometer was inserted subcutaneously into the abdominal wall for temperature recordings. A single intravenous injection of 5 per cent dextrose in Ringer's solution (20 cc. per kg. of body weight) was given each dog early in the day, and one-half hour later a blood sample was taken for hematocrit determination.

The dog lay upon his back in a wooden cradle. This was arranged on a table in such fashion that the cradle's height could be adjusted above the table, and by means of ropes and pulleys the dog could be tilted into a nearly upright position, a convenient arrangement for immersing the dog's hind extremities in warm baths just before and during perfusions, and for facilitating the measurement of leg volumes by water displacement.

With the hind legs outstretched, an incision was made longitudinally over the femoral vessels (Fig. 1) on the medial aspect of the thigh. The sartorius was retracted laterally, and the adductor longus medially. The femoral artery and vein, the long saphenous artery and vein, the popliteal artery and vein, and the short saphenous vein were exposed. The femoral nerve was spared. With this dissection completed, lymphatics of both the hind legs on the lateral

aspect of the calves just above the ankles were cannulated, and samples of lymph were collected until a constant range of readings for protein concentrations was obtained. Strap tourniquets were placed around each thigh and held close to the groins by the aid of brass cleats which were tied to the wooden cradle. The long saphenous artery was clamped close to its junction with the femoral artery and cannulated (Fig. 1). The short saphenous vein close to its junction with the popliteal vein was clamped and cannulated. Photographs of both hind feet were taken.

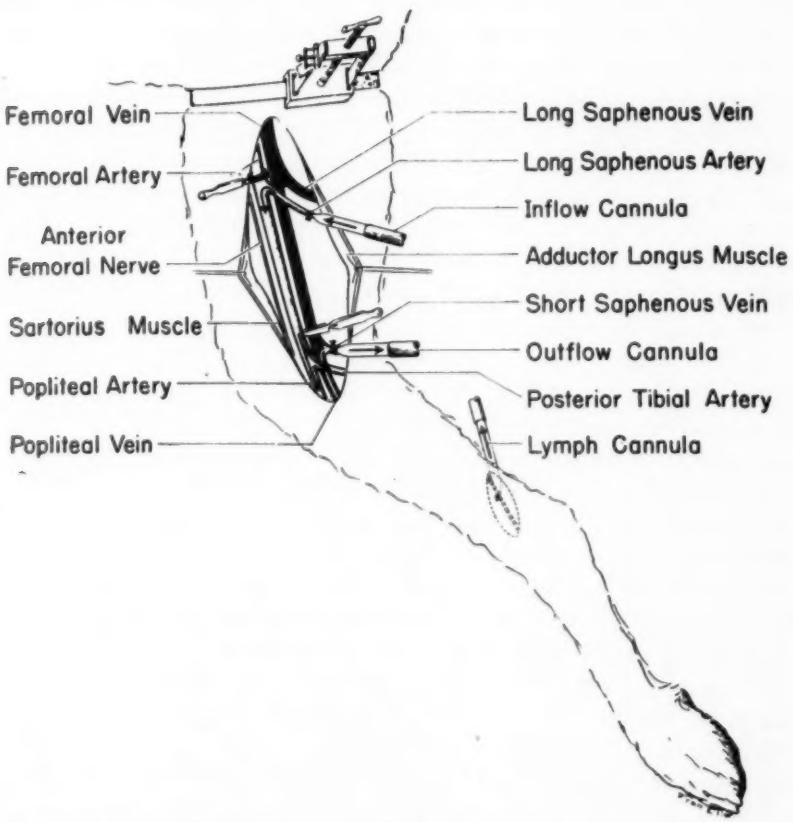

FIG. 1.—Diagrammatic representation of the dissection used in the perfusion experiments.

The dog's cradle was then elevated 18 inches off the table, tilted to a nearly vertical position, and volumes of both hind legs were determined by a water displacement method. Upon returning the cradle to the horizontal position, the hind legs to the ankle were immersed for 15 minutes in water heated to 50° C. This was done to obtain maximum vascular dilatation in the extremities before perfusion. The cannula in the long saphenous artery was attached to a supply bottle of normal saline and 6 per cent gum acacia solution adjusted to a pH of 7.0 with sodium hydroxide and ready to deliver the perfusate under 160 mm. Hg. of air pressure. The acacia solution in a water bath was held at a

fixed temperature, varying for different experiments from 38° to 75° C. An acacia solution was used for the perfusate, since it could be heated at random without the formation of precipitates and since it could be relied upon for the brief period of the perfusion to maintain the osmotic balance dependent normally upon the blood proteins. A kymographic tracing of arterial blood pressure was made at suitable intervals in each experiment.

To begin the perfusion, the arterial clip was shifted from the long saphenous artery to the femoral artery, and the perfusate began to flow up the long saphenous and down the femoral artery. To be certain that the leg was entirely isolated from the animal's own circulation, a tourniquet, shown at the top of Figure 1, was tightened strongly at the groin. This was always done in the perfused leg, and in many cases upon the opposite control leg so that the same period of vascular occlusion as regards normal blood supply would be experienced upon both sides. As is the case in human experience on occlusion of blood flow to the extremities, no alteration in the subsequent volume of the control leg was noted in such periods of asphyxia by blocked blood flow as have been used in these experiments. With the tourniquet upon the perfused leg tight, which required but a few seconds, the venous clip was shifted from the short saphenous vein to the popliteal vein. Gum acacia solution was run in for periods ranging from 4.5 to 20 minutes. The inflow temperature was recorded close to the inflow cannula. Outflow temperature and minute volume outflow readings were recorded at the delivery cannula three to four times during a single perfusion. The dog's subcutaneous temperature was taken before, during, and after the perfusion. At the end of the perfusion, the clips were shifted back to their original positions in the same order as above. The tourniquet was removed. A moderate amount of venous bleeding was allowed before shifting the venous clip, until such time as colorless or pale pink perfusate became dark red again, to prevent shunting the acacia solution contained in the leg vessels into the general circulation.

With the dog returned to his own circulation, the feet were removed from the hot baths, the cannulated vessels were tied off, the wound closed, and the feet were placed in nearly horizontal positions. Four- to 36-hour periods of observations were carried out following perfusions and included: Foot volumes; lymph flows; lymph protein concentrations; dog's temperature; arterial blood pressure, pulse and respirations; blood hematocrits; photographs of the hind legs; skin temperatures on the hind feet; and selected skin biopsies. The perfused vessels together with controls from the opposite leg were explored at the end of the experiment to observe the extent of subcutaneous edema and the ease with which bleeding occurred upon making incisions in the skin, and for any evidence of thrombus formation or damage to the vascular endothelium. Selected vessels were taken for microscopic study.

EXPERIMENTS

After some experience with the method, the question arose as to whether the local dissection and the application of a tourniquet contributed significantly

to changes in vascular permeability with subsequent swelling of the extremities. To answer this inquiry, both hind legs of two dogs were dissected, cannulae inserted, and the feet immersed in hot baths. Tourniquets were applied for 10-, 15- and 20-minute periods without perfusions; no swelling, not even transient, occurred in any foot. In 11 dogs, the vessels were dissected and a tourniquet applied to the control leg in a fashion similar to the one which was perfused. None of these control legs showed edema, increase in lymph flow, or changes in lymph protein content, while the perfused legs showed all the changes.

TABLE I

RELATIONSHIP BETWEEN DEGREE OF SWELLING OBSERVED IN DOGS' FEET AND INFLOW TEMPERATURE OF PERFUSATE WHILE PERFUSION PERIODS ARE UNDER 10 MINUTES AND PERFUSION RATES ARE OVER 25 CC. PER MINUTE

Dog No.	Weight	Period of Perfusion	Rate of Perfusion	Inflow Temperature	Outflow Temperature	Degree of Swelling
	Kg.	*Min.*	*Ml./min.*	*C.°*	*C.°*	
1	19	6	38	45	39	0
2	17	6	42	46	41	0
3	15	8.5	28	46.5	41	0
4	17	7	30	48	41.5	0
5	16	9	48	51	41	0
6	15.6	4	136	51	46	0
7	14.4	9.5	68	52	43	+
8	19	4.5	90	53.5	47	+
9	14.2	5.5	80	54	44	0
10	14	8	46	55	45	++
11	13.5	5	110	55	48	++
12	19	5	88	56	49	+
13	16.3	6	68	56	48	0
14	13.9	6.5	78	62	48	++++
15	15.3	5.5	36	64	47	+++
16	17.1	7	84	68	47	+++
17	14.7	6.5	50	68	50	+++
18	18	6	78	70	50	++++
19	16.4	6	34	75	50	++++

It is a natural speculation as to whether the perfusion with attendant anoxia contributed to our results. Several dogs were perfused with gum acacia solution heated to 38° C. for periods ranging from 4.5 to 13.5 minutes. One dog, perfused for 13.5 minutes with a very slow rate of flow (18 Ml. per minute), showed swelling, probably due to obstructed outflow. All dogs perfused under 10 minutes with flow rates better than 25 Ml. per minute showed no swelling.

In consequence of the above, perfusions were done for periods ranging from 4 to 9 minutes (average 6.04 minutes in 22 experiments), and flow readings ranging from 34 to 136 Ml. per minute (average 67 Ml. per minute in 22 experiments) were achieved. Table I is of interest with regard to these factors. When the rate of flow was brisk and the period of flow not too prolonged, the incidence and magnitude of swelling was in direct relation to the temperature of the perfusate. It is evident from this table that more than half

TABLE II

EXPERIMENTAL PROTOCOL OF DOG 12 WITH RIGHT LEG PERFUSED

Time	Comments	Nembutal 5%	Dog's Temp.	Foot Volume		Lymph Protein		Temperature of Foot Bath		Temperature of Perfusate		Perfusion Rate	Arterial Blood Pressure	Hematocrit
				Right	Left	Right	Left	Right	Left	Inflow	Outflow			
		Cc.	*C.°*	*Cc.*	*Cc.*	*Gm.%*	*Gm.%*	*C.°*	*C.°*	*C.°*	*C.°*	*Ml./min.*	*Mm. Hg.*	*%*
8:30	Dissection started	14												
11:00		2				2.32	1.21							
11:30	I.V. 300 cc.													
12:15						1.87								32
12:45		2												
1:15	Photos taken		36	210	185	1.76	1.37						216	
1:33		2												
1:35	Feet in hot bath							49	48					
1:55	Perfusion started		35							30	36		220	
1:57										50	41			
1:59										55	46	82		
2:01	Perfusion stopped		35					48	48	56	49	88	178	
2:17						1.26	1.17						180	
2:26				215	205									
2:37		2				1.46	1.20							
3:04													184	29
3:17						1.38	1.44							
3:45	Photos taken	2		240	190									
3:50						1.61	1.28						192	
4:30			35			1.51	1.51							
4:45														29
4:50	Photos taken			220	185								195	
5:00	Sacrificed													

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of the 13 dogs which were perfused with solutions below 56° C. showed no swelling at any time. Five dogs showed very mild swelling which frequently was transient and nearly subsided while the animals were under observation. Every dog perfused above 60° C. displayed marked swelling when, as in all

TABLE III

EXPERIMENTAL PROTOCOL OF DOG 19 WITH RIGHT LEG PERFUSED

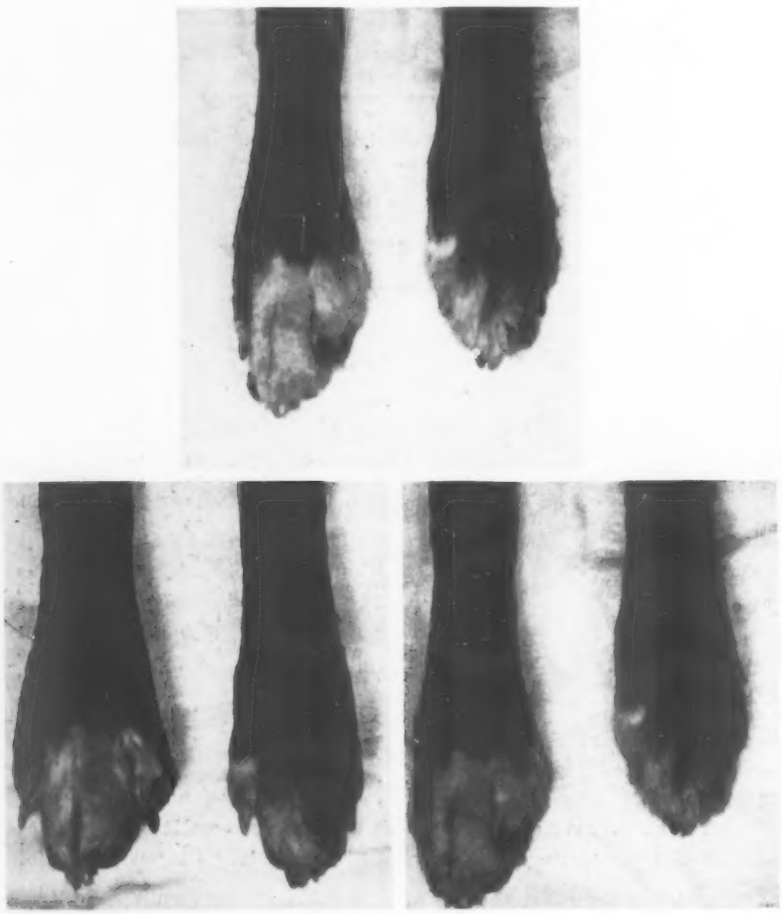
				Foot Volume		Lymph Protein		Temp. of Foot Bath		Temp. of Perfusate			Arterial Blood	
Time	Comments	Nembutal 5%	Dog's Temp.	Right	Left	Right	Left	Right	Left	Inflow	Outflow	Perfusion Rate	Pressure	Hematocrit
		Cc.	C.°	Cc.	Cc.	Gm. %	Gm. %	C.°	C.°	C.°	C.°	Ml./min.	Mm. Hg.	%
9:00	Dissection started	10												
11:45	I. V. 250 cc.					2.82	3.05							
12:00		2												
12:30						2.93	2.82							28
1:30	Photos taken	1.5	36	170	150									
1:35	Feet in hot bath							48	48					
1:54		1.5	36					48	48				172	
1:55	Perfusion started									50	36		108	
1:56										68	38	34		
1:57										71	48			
1:58			36					50	48	73	48	32		
1:59										74	50		198	
2:00			36					48	49	75	50	34		
2:01	Perfusion stopped													
2:15				195	160	2.79	2.77						176	
3:05						2.95	3.10						168	36
4:00		1.5	36			3.20	2.56						164	34
4:50	Photos taken	1		240	160								166	
6:00						3.38	2.85						166	
7:30	I. V. 250 cc.					3.48	3.15						164	42
8:30		1.5	35			3.36	3.01						166	
10:30	Photos taken	2	35	275	160	3.48	3.12						172	46
12:00		2	36.5			3.46	3.23						166	
3:00		2	37			3.22	2.80						166	47
4:45		1.5	36			5.21	2.80						168	
4:49						4.11	2.53						164	
6:30		2	37			4.83	2.36						162	
8:05		1.5	37			4.92	2.40						158	
9:30	I. V. 250 cc.	1.5	37	300	140	4.32	2.30						156	50
11:00	Plasma 250 cc.	1.5				4.75	3.28						140	
12:15	Photos taken	1.5	37			4.10	3.10						136	51
1:00	Sacrificed													

cases, normal circulation was restored. This was progressive while the animals were under observation.

Complete data from two experimental protocols are given in Tables II and III, illustrating in the one case the meager and readily reversible changes when the perfused solution entered at 56° C., and in the other case the severe and progressive changes observed when the perfusion solution entered at

75° C. The volume of the feet in both instances increased slightly during the immersion in the hot baths, but returned to normal fairly promptly on the control side. The volume of the foot perfused at 56° C. continued to swell slightly for two hours following the perfusion and removal from the hot bath (Fig. 2, A and B); subsequently the foot volume slowly returned towards

A



B C

FIG. 2.—Photographs of both hind feet of Dog 12, illustrating mild and transient swelling of the perfused right foot. (A) Just before; (B) 1.75 hours after; and (C) 3 hours after perfusion.

normal during the next hour (Fig. 2, C). On the extremity perfused at 75° C., however, the foot volume increased progressively during the 36 hours of observation following perfusion (Fig. 3). The protein content of lymph collected from the two legs of Dog 12 showed no change on the unperfused side, while the protein content dropped and the rate of flow increased for two hours

on the perfused side. These changes were followed during the next two hours by a diminution in rate of flow and a reversion towards normal of the protein concentration. In Dog 19, on the other hand, the lymph protein content during the observation period steadily rose; simultaneously the flow increased and the color of the lymph became pink. Microscopic examination of the lymph revealed numerous free erythrocytes in small clumps. The systolic arterial

FIG. 3.—Photographs of both hind feet of Dog 19, illustrating the severe and progressive swelling of the perfused right foot. (A) Just before; (B) 3.75 hours after; and (C) 22 hours after perfusion.

blood pressure of Dog 12 was sustained throughout the experiment, and hematocrit measurements showed no significant alterations. Upon the introduction of the hot perfusate in Dog 19, there was a transient drop in systolic arterial blood pressure accompanying severe sensory stimulation; this was quickly restored before the six minutes of perfusion were completed. During the following 36 hours, however, there was a very gradual drop in blood pressure

and increasing hemoconcentration with a rising hematocrit. At the time of sacrifice of Dog 12, incision made into the dorsum of the perfused foot showed no subcutaneous edema and considerable free bleeding from transected blood vessels. No vascular thromboses were detected upon dissecting the major arterial and venous trunks. In Dog 19, on the other hand, incision into the dorsum of the perfused foot displayed copious amounts of subcutaneous edema and no free bleeding. Upon dissecting the major vessels there were freshly formed, friable clots in the femoral artery and popliteal vein.

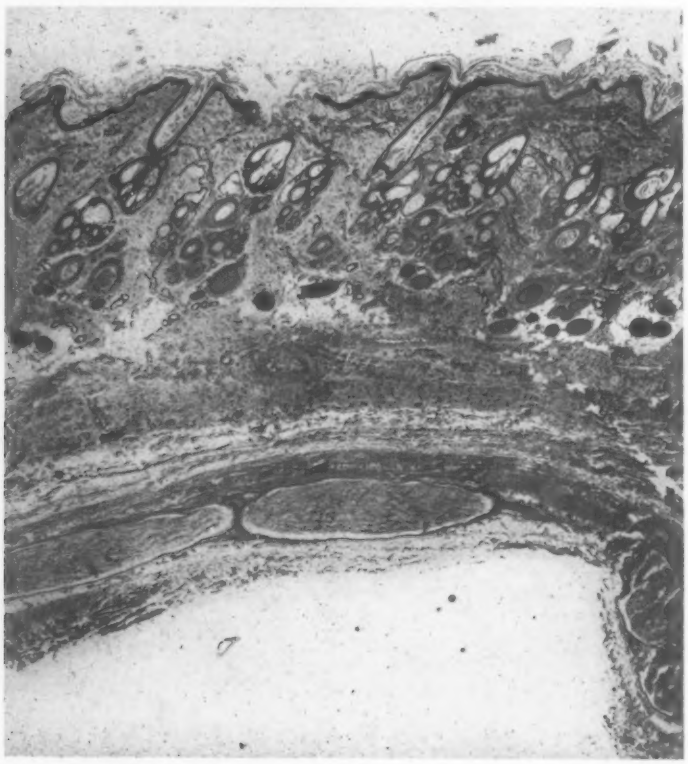


FIG. 4A.—Microscopic view of skin biopsy from the perfused right hind leg of Dog 12, illustrating no changes. (×40)

Pathologic studies were carried out on all experimental subjects. Selected skin biopsies were taken from the web space and dorsum of each hind paw. Transverse sections were made across segments of femoral and popliteal arteries as well as femoral and popliteal veins. These were fixed in Zenker's solution and stained with eosin methylene blue. In addition, segments of popliteal veins were slit longitudinally, washed with distilled water, stained on the endothelial surface with 10 per cent silver nitrate solution for one minute, washed again with distilled water, and fixed in 10 per cent formalin. By this technic, refined by O'Neill,[5] the intercellular cement of the endothelium was visualized together with the geometric pattern of the endothelium.

Microscopic examination of skin biopsies showed no abnormalities in the control legs and no changes in legs perfused from 4 to 9 minutes with the gum acacia solution heated up to 60° C. (Fig. 4A). Above this threshold of temperature or beyond 10 minutes' perfusion time, sections from swollen feet showed subcutaneous edema, congested capillaries, widely dilated lymphatics, and erythrocytes extravasated into the intercellular spaces (Figs. 4, B; and 5). With the silver nitrate technique, the endothelial coat of veins from

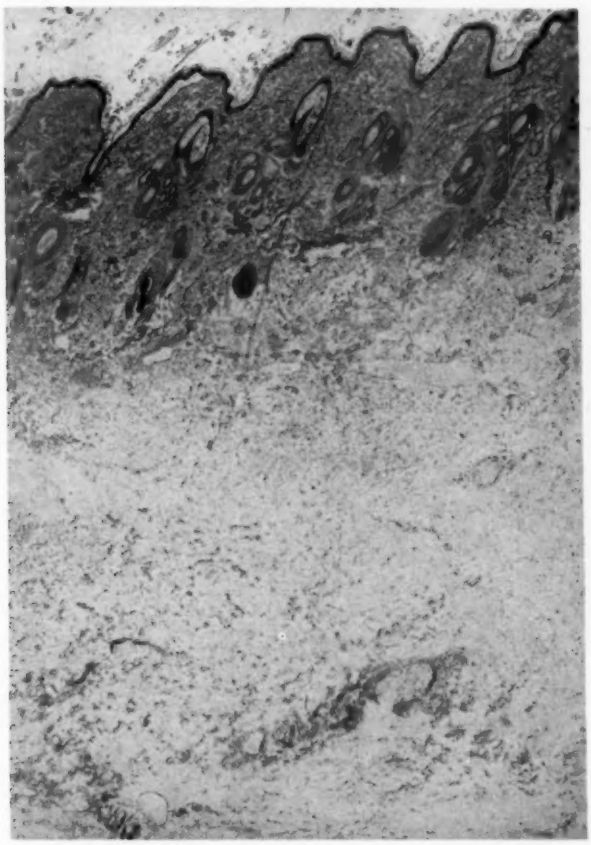


FIG. 4B.—Microscopic view of skin biopsy from the perfused right hind leg of Dog 19, illustrating subcutaneous edema, congested capillaries, widely dilated lymphatus, and erythrocytes extravasated into the intercellular spaces. (× 40)

control legs and from legs perfused for short periods of time at appropriately low temperatures appeared intact and uniformly symmetrical (Fig. 6, A). Legs which had progressive swelling following perfusions above 60° C., on the other hand, showed a disruption of the geometric endothelial pattern with fragmentation and disappearance of lining cells (Fig. 6, B).

One further consideration was the total amount of perfusate run in and recovered from the outflow cannula. Total inflow readings ranged from 215 to

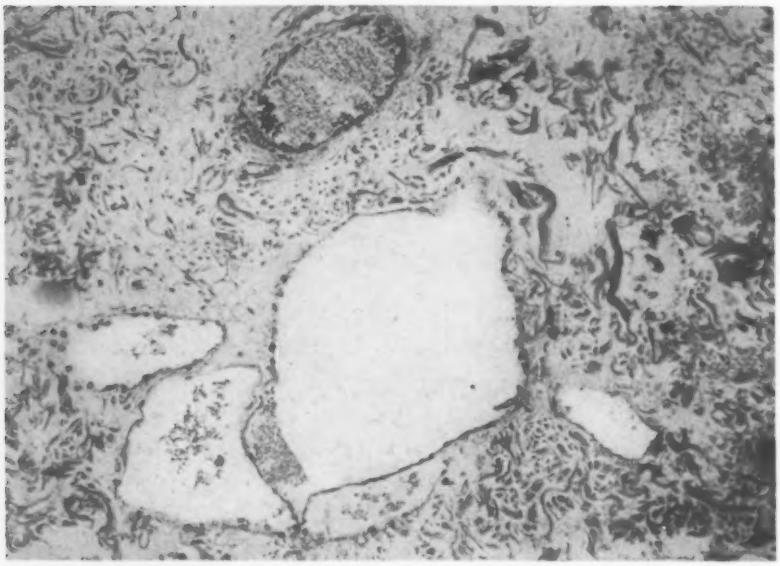


FIG. 5.—High-powered microscopic view of the skin biopsy from the perfused leg of Dog 19, emphasizing the wide dilatation of the lymphatics, congestion of the capillaries, and extravasation of erythrocytes. (x 90)

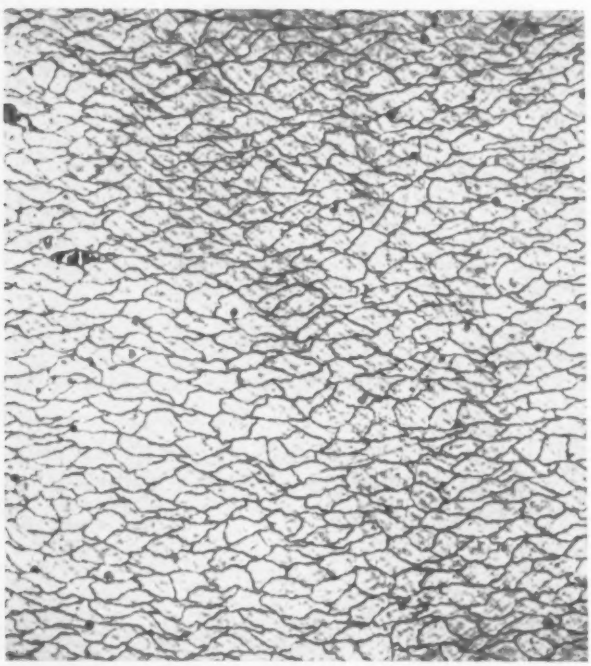


FIG. 6A.—Microscopic view of the endothelial pattern of the intact endothelium of the popliteal vein from the control leg of Dog 19. (× 60)

520 cc. (average 337 cc. in 17 experiments), and total outflow readings ranged from 150 to 535 cc. (average 320 cc. in the same 17 experiments). In most instances the inflow and outflow were nearly equal, but in experiments in which the outflow was more or less than the inflow there was no correlation with the incidence of swelling.

DISCUSSION.—The data from these experiments can by no means settle the much debated problem concerning the etiology of the systemic effects of

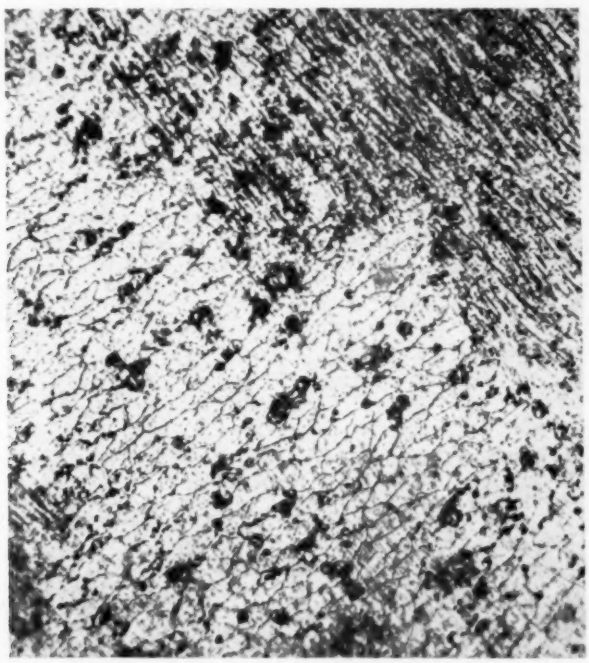


FIG. 6B.—Microscopic view of endothelial pattern of the fragmented endothelium of the popliteal vein from the perfused leg of Dog 19. (× 60)

thermal burns. Like other workers,[6, 7] we have no evidence of the existence of immediate shock under the experimental conditions described above. Whether the systemic changes in blood pressure and hemoconcentration, as indicated in Table IV, are due to the release of toxic substances (Wilson, *et al.*[3, 8]) or are due to the shift in body fluids (Blalock[9] and Harkins[6]), or both, continues to remain an unanswered question. In view of the fact that several of our perfusion experiments were done under complete aseptic surgical conditions, we believe that neither bacteria nor bacterial toxins have contributed to our findings. Aldrich[10] has made clear, however, that bacteria play little rôle in burns during the first 36 hours, the longest time during which our animals were studied.

In the investigation of the rôle of hypoxia and anoxia in these experiments, these findings are in general accord with those of Kellaway and Rawlinson[11]

who perfused the isolated lungs of guinea-pigs with saline. Their perfusions were, however, carried out over six-hour periods, and they concluded that anoxia does not cause any gross injury to tissue cells and is unlikely to aggravate heat injury to any significant extent. Six per cent gum acacia solution was used in the experiments reported in this paper in order to provide the colloid osmotic pressure of normal circulating blood plasma. With this solution warmed to 37° C., it was found that perfusions for increasing intervals of time beyond 10 minutes were attended by increasing amounts of swelling. Within this time limit, however, hypoxia did not appear to alter vascular permeability.

In their third paper, Kellaway and Rawlinson[12] studied the effects of hot saline perfusions on the isolated hind limbs of guinea-pigs and the fore limbs

TABLE IV

RELATIONSHIP BETWEEN DEGREE OF SWELLING AFTER PERFUSION AND CHANGES IN ARTERIAL BLOOD PRESSURE AND HEMATOCRIT

		Arterial Blood Pressure			Hematocrit			
Dog No.	Weight	Before Perfusion	End of Experiment	Net Change	Before Perfusion	End of Experiment	Net Change	Swelling
	Kg.							
6	15.6	192	178	−14	35	40	+ 5	0
9	14.2	178	162	−16	31	25	− 6	0
13	16.3	170	166	− 4	28	36	+ 8	0
7	14.4	230	196	−34	30	32	+ 2	+
2	19	216	194	−22	32	29	− 3	+
10	14	180	182	+ 2	20	33	+13	++
11	13.5	176	142	−34	28	31	+ 3	++
15	15.3	166	134	−32	31	36	+ 5	+++
16	17.1	220	156	−64	33	39	+ 6	+++
14	13.9	216	224	+ 8	30	49	+19	++++
18	18	168	144	−24	25	45	+20	++++
19	16.4	172	136	−36	28	51	+23	++++

of cats. Again their perfusions were carried out over periods lasting several hours. They washed the vascular tree free of blood constituents by running through approximately a liter of saline at a rate of 10 to 15 Ml. per minute, and then continued their perfusion for several hours at a rate of about 1 to 2 Ml. per minute, high rates of flow for simple saline solutions. Under more precise experimental conditions with an intact animal, it is indicated that the duration and rate of flow of the perfusion play a rôle in altering the permeability of the vascular endothelium as judged by the incidence of leg swelling, rate of lymph flow, and alterations of lymph constituents.

SUMMARY

1. A new method for perfusing the vascular tree of the hind extremity of the intact dog has been described. A solution of normal saline and 6 per cent gum acacia solution at a pH of 7.0 was the perfusate.

2. The results of employing this technic for the study of the effects of heat on the permeability of the vascular endothelium and neighboring structures locally are described and discussed.

3. In addition, observations on the systemic effects of such burns on the animal generally are reported.

4. A new method, from O'Neill's[5] unpublished work, has permitted examination of the cellular pattern of the vascular endothelium.

The authors wish to express their profound gratitude to Dr. Cecil K. Drinker for his many helpful suggestions and sympathetic supervision while this work was being conducted in his laboratory.

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HOMOGENOUS FETAL CARTILAGE GRAFTS TO BONE

AN EXPERIMENTAL STUDY

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PREVIOUS EXPERIMENTAL WORK with diced cartilage has proved that autogenous grafts survive transplanting and in some cases exhibit growth. Studies conducted here have confirmed these findings.[1] We observed viable cartilage three months after grafting into a long-bone defect in a rabbit. Replacement by bone was exceedingly slow. It was decided to investigate the reactions in adult long bone when a defect was repaired with diced homogenous fetal cartilage.

Fetal tissues have received considerable attention in recent years. Pure strains of cartilage cells from chick embryo were grown *in vitro* by Fischer[2] on embryo media for over three months. Fell[3] was able to show that isolated fowl femora 5.5–6 days old had a capacity for self-differentiation and *in vitro* increased to three times their size with no change in gross proportions. Histologically, they had a normal cellular differentiation. She was able to show that a phosphatase was liberated *in vitro* and this enzyme was produced only when large hypertrophic cells were present.

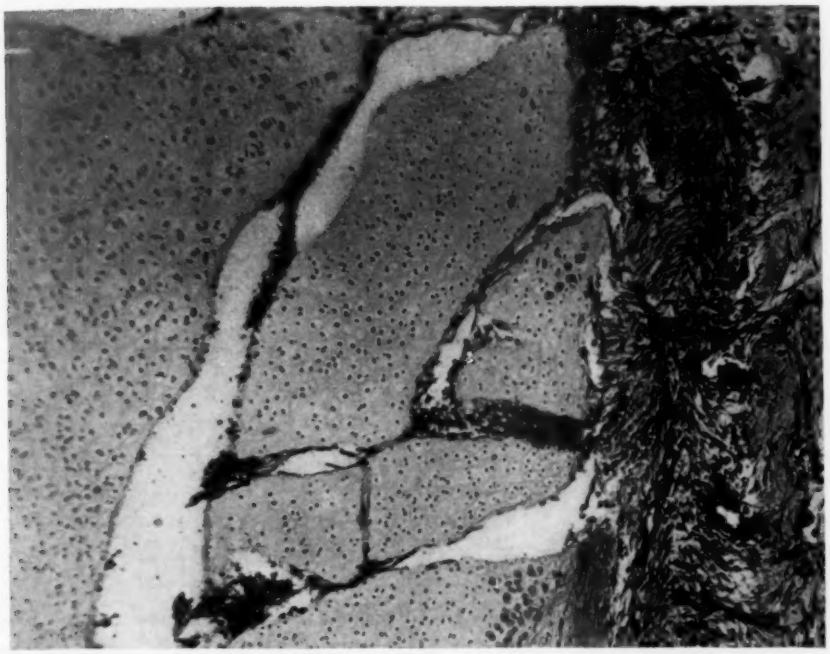
In subsequent work Fell and Robison[4] confirmed the need for hypertrophic cartilage cells in the production of phosphatase. They were able to observe osteogenesis in mandibular mesoderm around Meckel's cartilage of fowl by hanging-drop tissue culture methods.

This means that tissue culture methods have proven early cartilage has the propensity for self-differentiation *in vitro,* as well as the production of phosphatase.

Transplanted epiphyseal cartilage has also been studied. Early continental observers had suggested that when epiphyseal cartilage was grafted to a bony site it continued to grow. In fact, Straub's[5] case of an epiphyseal bone transplant in a boy, with excellent clinical results 16 years postoperatively, strongly suggested this. Nevertheless, after intensive experimental study Haas[6] was able to conclude that the epiphyseal cartilage plate loses its ability to produce length growth after transplanting. This was confirmed by Bisgard's[7] work with goats.

Embryonic cartilage *in vitro* has the power to grow, to differentiate and to liberate phosphatase. Yet, when epiphyseal cartilage, itself actively growing and undergoing replacement by bone, is transplanted, some of these potentialities are lost. This study is an endeavor to ascertain the histologic reactions involved when healthy young fetal actively growing cartilage is transplanted into adult long bone.

FIG. 1



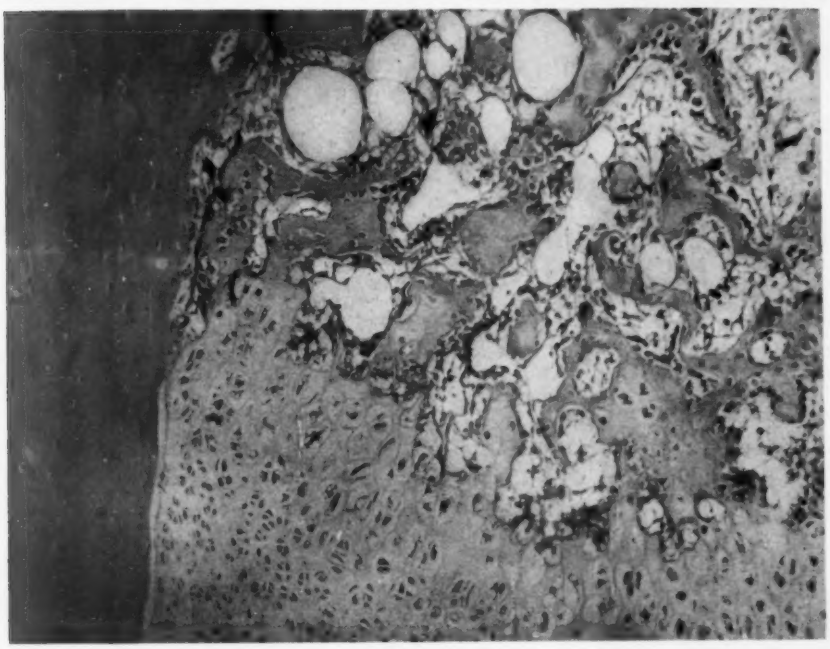


FIG. 2

FIG. 1.—Four days postoperatively: Several dices of fetal cartilage lie within the defect. Each is filled with deeply-staining cartilage cells, two or three to a lacuna. An ingrowth of connective tissue cells has begun to surround the dices.

FIG. 2.—One week postoperatively: One corner of a cartilage dice is shown, evidently through an epiphyseal line, with solid cortical shaft bone beside the graft. Considerable cancellous bone is replacing the cartilage, which is invading in normal patterns.

FIG. 3

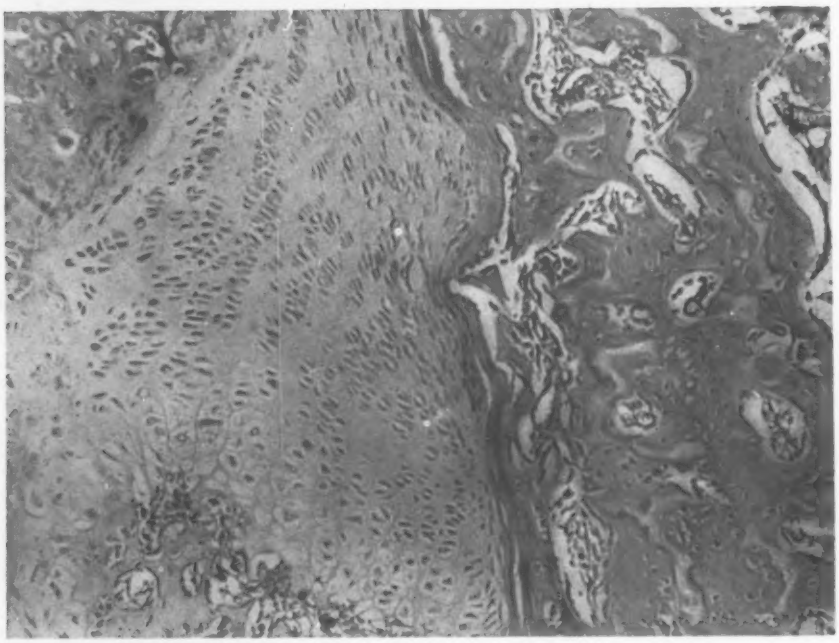


FIG. 4

FIG. 3.—Two weeks postoperatively: The dices of cartilage have been invaded by tongues of absorption. These tongues are partially occupied by deeply-staining cells and débris. The cartilage cells appear in enlarged lacunae, and most lacunae have only one cell within them.

FIG. 4.—Three weeks postoperatively: One corner of a dice of fetal tissue is seen surrounded by active cancellous bone. The chondrocytes are arranged in layers and flattened. Towards the line of ossification some lacunae are enlarged and empty, and communicate with the medullary cavity.

Material.—A supply of fetal material was obtained by removing uterus and feti from a near-term female rabbit. Under sterile conditions the long bones of the unborn rabbits were dissected out and the cartilaginous epiphyseal ends removed. These were diced into approximately 0.5 mm. cubes and preserved in sterile saline solutions.

Method.—The experimental animal was anesthetized and a long bone of the forelimb exposed. A defect, one-half-inch in diameter, was created on the cortex and extended into the medulla. No complete fracture of the bone was made. Into this defect the fetal cartilage dices were packed tightly and held in place by the periosteum and tendon of the limb. The incision was closed with black silk and collodion dressings applied. No immobilization was used, the animal being free as soon as consciousness was regained.

Fifteen such animals were used, and were sacrificed at four days, one week, and thereafter at weekly intervals. Sections were taken in the axis of the limb through the defect to show normal shaft on either side of the cartilage grafts. After decalcification they were stained with hematoxylin and eosin.

RESULTS

Four days postoperatively: Many dices of cartilage are seen completely filling the defect. Each dice shows marked cellular activity, with lacunae well-filled with two or more cells, many of which are undergoing division. Surrounding each dice are ingrowths of connective tissue cells, growing parallel to the dice surface. There is no evidence of cartilage necrosis or reaction by the host to the homogenous material.

One week postoperatively: Cartilage cells are still filling the lacunae but on one side, evidently the epiphyseal line, the process of ossification is continuing with large cystic-like lacunae being invaded by tongues of bone.

Two weeks postoperatively: Dices of cartilage have lost their solid appearance and appear "motheaten." Defects throughout the matrix exist in the form of wide channels. These are lined with deeply-staining cells, running parallel to the wall. The cartilage itself is less cellular, the lacunae larger and incompletely filled by chondrocytes. Each cell stains deeply, many clinging to the lacunar walls, some pyknotic and a few round and pale. Some lacunae appear to be coalescing. Cancellous bone surrounds the dices.

Three weeks postoperatively: Each dice is well-surrounded by cancellous bone, the matrix of which becomes continuous with the cartilage matrix. Chondrocytes stain well and are arranged in flattened "piles," as in a healthy epiphyseal line. Ossification is progressing from one side. Here, large empty lacunae communicate with the medullary cavity.

Six weeks postoperatively: All dices are now firmly bound together by connective tissue and cancellous bone. There is continuity of bone and cartilage matrices. Invasion of the dices by large channels continues but these inroads are for the first time filled with clumps of deeply-staining round cells. These tend to line the channel walls.

Seven weeks postoperatively: The remains of cartilage dices are seen as

FIG. 5

FIG. 6

FIG. 5.—Six weeks postoperatively: A portion of cartilage is firmly embedded in cancellous bone. Some lacunae are cystic and enlarged, while others contain many chondrocytes and some mitotic figures are seen in these latter. The matrices of surrounding bone and cartilage are continuous. The tongue of absorption contains many small deeply-stained round cells.

FIG. 6.—Seven weeks postoperatively: A small island of cartilage completely buried in cancellous bone. Some lacunae contain deeply-stained chondrocytes.

FIG. 7

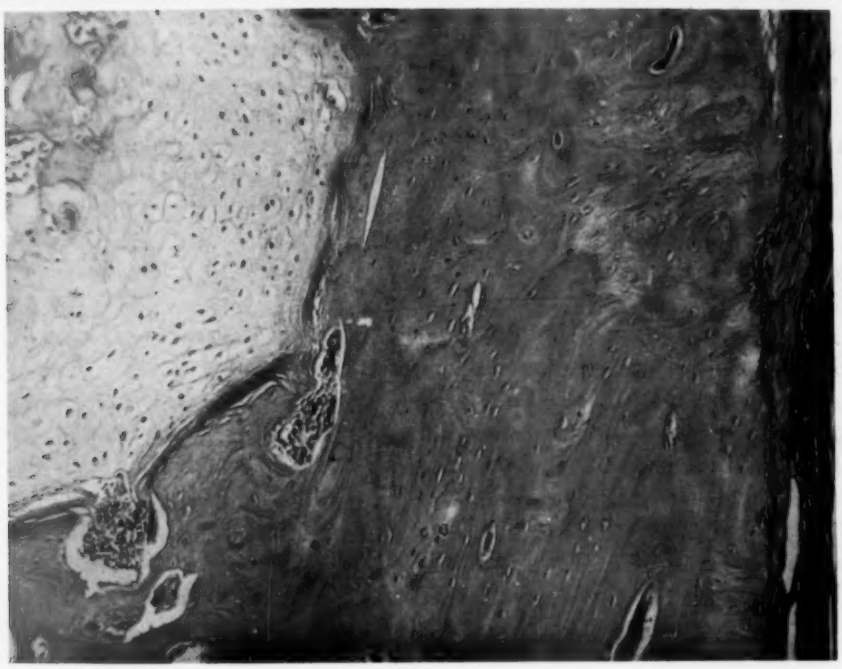


FIG. 8

FIG. 7.—Eight weeks postoperatively: A portion of diced cartilage is seen surrounded by cancellous bone trabeculae, with continuity of bone and cartilage matrix. The spaces between trabeculae contain many deeply-staining round cells.

FIG. 8.—Ten weeks postoperatively: A small portion of fetal cartilage is seen in contact with more or less solid bone. The dice shows some empty lacunae. Some contain deeply-staining cells, but all lacunae are enlarged and appear to be undergoing replacement.

islands of cartilage more or less walled-off by cancellous bone. Many lacunae retain two or more cells, but these are larger and paler than formerly, and a few lacunae are empty. Round cells buried in meshwork line the walls of bony trabeculae.

Ten to 12 weeks postoperatively: Islands of cartilage remain completely surrounded by thickened cancellous bone. Lacunae are enlarged and some in the central portions of the grafts are empty, cystic and tend to coalesce. Many, however, retain deeply-staining nuclei of chondrocytes, but all evidence of mitosis has disappeared. A few scattered tongues of erosion are seen between cartilage and bone. These contain many deeply stained cells but no giant cells.

Discussion.—If transplanted epiphyseal cartilage continued to grow at the rate of untransplanted cartilage, and if replacement by bone followed the normal pattern, one could expect bizarre exostoses to result from such grafts. That this is not the case is now evident. We must conclude that while homogenous grafts survive for the most part, propensity for growth is generally lost. Replacement by bone follows the scheme already established for autogenous cartilage grafts to bone.

When homogenous tissues are grafted, a reaction to the foreign material is observed. It is minimal in cartilage and corneal grafts. This takes the form of a lymphocytic reaction which reaches its peak around 30–50 days after transplanting and then falls off gradually (Loeb[8]). We believe the clumps of deeply-staining round cells seen first in the six-weeks specimen represents this lymphocytic reaction against fetal homogenous material. It is interesting to note that in fowl, which normally have a higher percentage of lymphocytes than mammals, this reaction reaches such proportions as to absorb homografts entirely (Loeb and Siebert[9]).

CONCLUSIONS

1. Fetal rabbit cartilage, when diced and grafted into a long bone of an adult animal will survive up to three months.

2. Slow replacement by cancellous bone from the host takes place, similar to the replacement of autogenous diced cartilage grafts.

3. No evidence, gross or microscopic, is found that fetal tissue after homografting retains any great propensity for growth or differentiation.

4. A mild localized round cell reaction is observed to reach its peak about six weeks after transplanting.

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ACROMIOCLAVICULAR DISLOCATION

END-RESULTS OF SCREW SUSPENSION TREATMENT

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AMONG the various operative methods for the repair of complete acromioclavicular dislocation which have been advocated are fascial suture,[1, 2] wire fixation,[3, 4, 5] and excision of the tip of the clavicle.[6, 7] The proponents of each of these procedures have reported favorable results in their own hands.

It is now six years since I introduced treatment by screw suspension.[8] In a little over a year, from December, 1940, to January, 1942, I performed this operation upon eight patients. This is a report of the end-results of each of those operations. Nine additional cases in which this method was used by other surgeons are included in the clinical protocol, although they are excluded from the summary of end-results, as none of them was ever seen by me personally.

This operation was designed temporarily to maintain reduction of a complete acromioclavicular separation by the insertion of a single vitallium screw, under local anesthesia, through the outer portion of the clavicle into, and through, the underlying coracoid process of the scapula. Subsequent to publication of my original paper the same operation was independently devised by Vere-Hoge in England. It was used successfully there in the treatment of air casualties of the recent war.[9]

In each of my cases the screw alone was depended upon for full support during the period of healing. Although a sling was always prescribed postoperatively no patient wore it more than a few days because of the relief and feeling of well-being experienced as a result of the screw support.

Seven of my cases were freshly incurred injuries but one of them became a three-month-old redislocation, with a frozen shoulder, before final and successful repair. One other came to me as a two-month-old injury, with frozen shoulder. The patients varied in age from 23 to 74 years and, in physique, from paratroopers to elderly ladies. All were operated upon in the hospital, with full operating room facilities and assistance available. They spent only one night in hospital (with the exception of the two cases of frozen shoulder which were kept longer for traction suspension following freeing of the adhesions about the shoulder joint). One patient went home the day of operation.

In no case in which the newly designed flanged screw was inserted through both cortices of the coracoid process did it pull out, even partially; nor did the original fine-threaded screw pull out in three of the four patients in whom it was used. In two cases the screw broke without pulling, with one failure in a man who refused reoperation and one success, with permanent reduction and full function. The screw was removed from two of my

patients, at six and seven weeks, respectively, with no recurrence of dislocation in either one. No screw has ever migrated to another part of the body.[10]

Callus and bone, visible by roentgen ray, have developed within the substance of the coracoclavicular ligaments to some extent in every case. At times this has resulted in the formation of a considerable mass of bone but with no interference with function. Absorption of bone about the screw threads has occurred without affecting the end-result in any way, but it seems to be the exception rather than the rule when the screw is properly placed.

Six of my patients have now been followed, with personal examination, over four years, two of them more than five years, since operation. Another was last seen at two years and three months and another at six months. In six patients perfect reduction and function of the acromioclavicular joint have been preserved by the screw repair. One patient has perfect function and has been doing heavy work for three years although the screw pulled a quarter of an inch. Another completely redislocated after the screw broke at four weeks and the patient has refused further treatment.

If the results in these eight cases are considered with respect to anatomy (A), economics (E), and function (F), and are graded from 0 to 4 (0 denoting failure and 4 being excellent), they may be summarized as follows: Six cases—A4—E4—F4; one case—A3—E4—F4; one case—A0—E2—F2.

Details of the operative technic have already been published.[8] The following modifications have been made as the result of added experience:

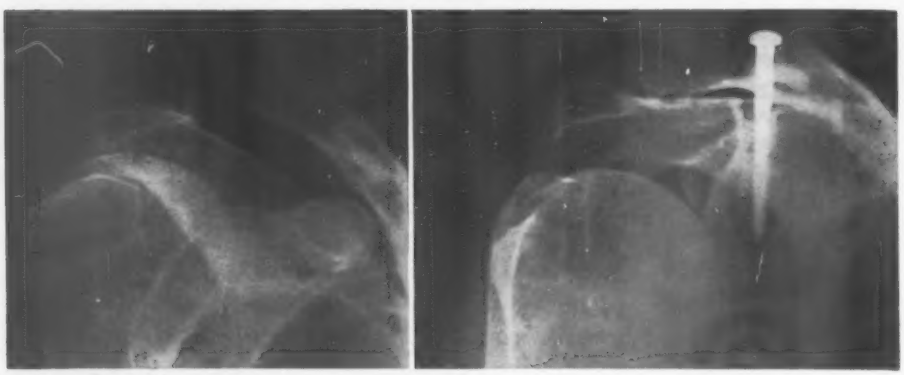
(1) *The Screw and Its Implantation.*—Only a screw of an electrolytically inert material, having a wide-flanged thread of minimal pitch and a broad, flat head, should be used. In most patients the one and a half-inch screw will grip the under surface of the coracoid adequately with the acromioclavicular dislocation reduced. Occasionally, when the distance between coracoid and overlying clavicle, following reduction, is greater than normal (one-half inch) or the individual has very large bones, it may be necessary to employ the one and five-eighths or the one and three-quarter-inch screw.

Complete reduction must be secured before the hole in the clavicle is drilled and the screw inserted so that proper direction of the screw is assured. A tiny hole may be made with an awl in the upper surface of the coracoid to start the screw but the coracoid must not be drilled and the screw must penetrate both cortices of that bone.

Roentgenograms taken during operation have proven superior to fluoroscopy as a means of checking placement of the screw. It is more comfortable for the patient, and easier for the surgeon, if the patient is supine on the table rather than sitting in a chair during the operation. The clavicle depressor originally recommended[8] has been found unnecessary.

(2) *Postoperative Care.*—Although my patients have all regarded a sling as a nuisance, it is an excellent psychologic adjunct to treatment, for it serves as a constant reminder of their potential infirmity until soft-tissue support is attained. The sling should be removed at times during the day and the pa-

tient encouraged to do arm-swinging exercises and "crawling up the wall." He should also be allowed to bathe, dress and feed himself, to shave and to brush and comb his hair, all from the day after operation. In between these activities, and at night, a sling should be worn for the first eight weeks. Any heavy work during this period must be interdicted by the surgeon in no uncertain terms and he should see the patient frequently to make sure that these orders are obeyed. The screw may be left in place indefinitely or removed after eight weeks.



A B

FIG. 1.—Case 1: P. B., housewife, age 74.

A. Before operation.
B. Five years and 4 months result with old type screw. A4—E4—F4.

CLINICAL PROCTOCOLS

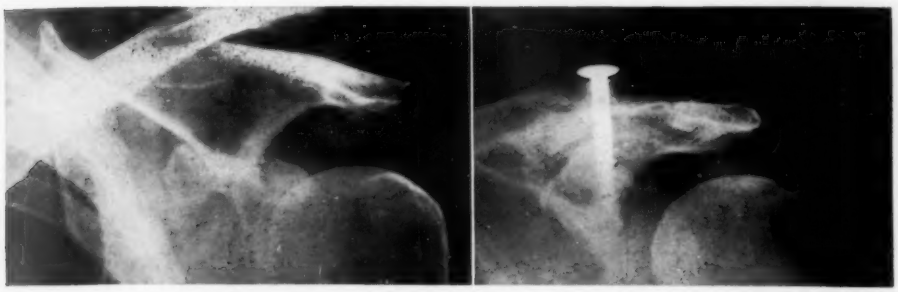
Author's Cases:

Case 1.—P. B., the first patient to undergo this method of repair was operated upon 12-14-1940, at age 74.[8] She had sustained a complete right acromioclavicular dislocation from a fall three days before operation (Fig. 1A). Severe generalized arthritis made immobilization of the upper extremity inadvisable. Personal examination over five years after operation reveals no gross deformity, no limitation of motion and no impairment of strength compared with the other shoulder. This in spite of the fact that two months after operation she fell downstairs again and pulled the screw about one-eighth inch as shown by roentgen-ray.

COMMENT: In view of the fact that later roentgenograms (Fig. 1B) showed absorption of bone about the screw it is obvious that permanent maintenance of reduction is dependent, as was anticipated, upon firm healing of the soft-parts and not upon the screw. The formation of bone between coracoid and clavicle is interesting. Five years and four months result: A4—E4—F4.

Case 2.—M. B., was operated upon 2-7-'41, at the age of 73,[8] ten hours after she had fallen from a chair. The tip of the clavicle was displaced 1.5 inches above the acromion and nearly compounded the overlying skin (Fig. 2A). An excellent reduction

was secured, but at three weeks she did heavy housework, against advice, and redislocated. The same screw was replaced but failed to hold. Three months after the original operation this screw was removed and replaced, under direct vision, with a specially designed flange-threaded screw. At the same time adhesions which had formed about the shoulder



A B

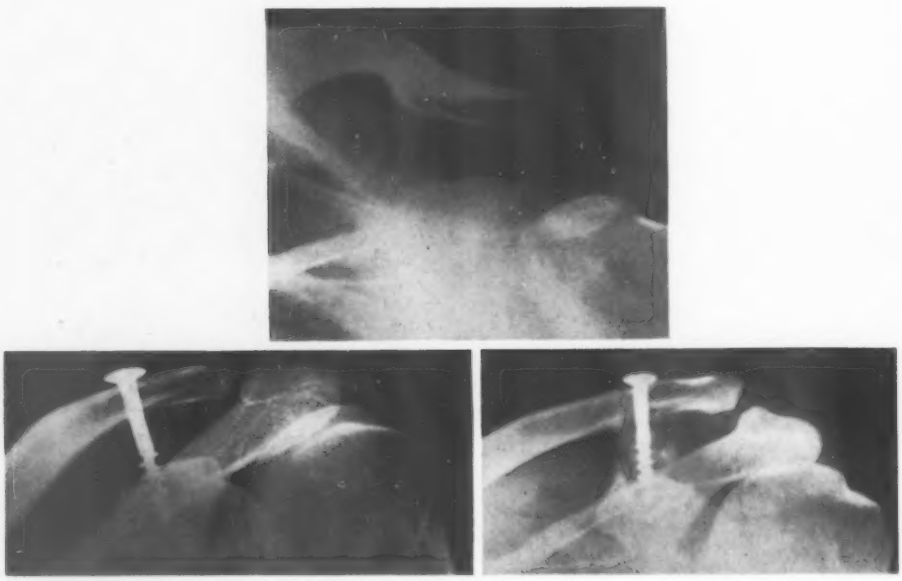
FIG. 2.—Case 2: M. B., housewife, age 73.
A. Before operation.
B. Five years and 2 months result. A4—E4—F4.

FIG. 3.—Case 3: J. M., laborer, age 65.
Two years and 3 months result with old type screw which broke. Patient refused reoperation. A0—E2—F2.

joint were broken up by manipulation under general anesthesia. Clinically, the patient has no complaints referable to the injury or repair. She does all her own housework. There is no deformity, no loss of strength and she has full active motion in the affected shoulder.

COMMENT: This case proves that screw suspension can be used successfully in an old persistent dislocation even in the presence of a frozen shoulder severe enough to require manipulation under anesthesia. The lack of bone absorption about the screw threads is noteworthy as is the production of new bone in the soft-tissues between coracoid and clavicle (Fig. 2B). Note that the screw penetrated both cortices of the coracoid. Five years and two months result: A4—E4—F4.

A



B C

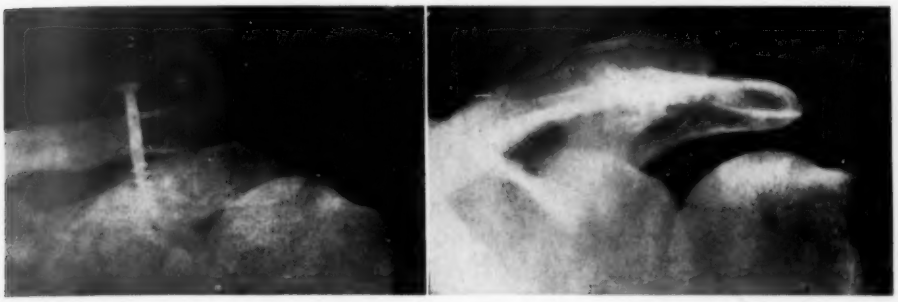
FIG. 4.—Case 5: E. G., laborer, age 27.
A. Before operation.
B. Screw not inserted deeply enough.
C. Four years and 10 months result. A3—E4—F4. Excellent function although screw had pulled slightly.

Case 3.—J. M., was operated upon 2-20-1941, at the age of 65.[8] A fall on the ice two days previously had resulted in a complete right acromioclavicular dislocation. Full reduction was not secured at the time of operation. The old style screw was used and at four weeks it broke, with recurrence of dislocation (Fig. 3). This patient persistently refused reoperation with the new type of screw. When last examined, two years and three months after operation, his only complaint was of occasional pain in the affected shoulder and weakness in the arm.

COMMENT: Partial reduction placed the screw at a great mechanical disadvantage and subjected it to increased stress, yet, because the screw was inserted through both cortices of the coracoid it did not pull out—it broke. The result at two years and three months, must be classed as an operative failure, patient refusing further treatment: A0—E2—F2.

Case 4.—A. M., was operated upon 2–20–1941, at the age of 34, for a complete left acromioclavicular dislocation.[8] This was a compensation case involving a highly nervous, very apprehensive individual whose injury was the result of a fall the day before operation. Roentgenograms[8] and clinical examination at seven weeks showed excellent reduction with complete, strong painless function. However, patient worried constantly about having a metal screw in her shoulder and it was removed by another surgeon. When patient was last seen by me, six months after the original operation, there were no complaints referable to the shoulder and she had been doing heavy work as a masseuse for three and a half months. There was no deformity, no limitation of motion, no weakness and no pain.

COMMENT: The screw in this case was placed through both cortices of the coracoid and though it was of the old fine-threaded variety it held securely until it was removed. Six months result: A4—E4—F4.



A B

FIG. 5.—Case 6: C. P., athlete, age 24.
A. Screw not inserted deeply enough.
B. Four years and 6 months result. Note abundant callus. Served overseas as paratrooper. A4—E4—F4.

Case 5.—E. G., was operated upon 4–23–1941, at age 27, for a complete left acromioclavicular dislocation (Fig. 4A and B) resulting from a fall on the shoulder a day or two before. This patient resumed heavy work in less than four weeks, against advice. Recently, five years since operation, this patient writes from California: "I have been doing heavy work now for about three years. The screw is still where you put it. I hardly ever give it a thought any more as my left shoulder don't pain or bother me." Roentgenograms (Fig. 4C), taken 2–5–1946, show slight pulling of the screw with new bone formed about the shaft and no absorption about the screw threads.

Case 6.—C. P., at the age of 24, suffered a complete left acromioclavicular dislocation when he was struck forcibly on the point of the shoulder by another man's head during a baseball game. Operation was performed, 8–22–1941, one week after injury, with the new flanged screw. In this case, also, the screw pulled slightly (Fig. 5A). At six weeks the screw was removed, under local anesthesia. This patient was a big, heavily-muscled young man who was accepted for enlistment in the air corps within one year after operation. Later, he served as a paratrooper in the Pacific. Examination, 2–5–'46, revealed an apparently normal shoulder. There was no pain, limitation of motion, deformity or weakness. Roentgenograms (Fig. 5B) show maintenance of good reduction, with a heavy mass of bone apparently uniting the coracoid to the overlying clavicle. On roentgenograms taken in other planes, however, a pseudarthrosis can be seen to traverse this bony mass horizontally.

COMMENT: In both the preceding cases, the screw was not inserted far enough to grip both cortices of the coracoid and the patients resumed heavy work, against advice, too soon. Four years and ten months result in Case 5: A3—E4—F4. Four and one-half years result in Case 6: A4—E4—F4.

Case 7.—R. H., at the age of 23, sustained a complete right acromioclavicular dislocation (Fig. 6A) by landing on the point of his shoulder while making a flying

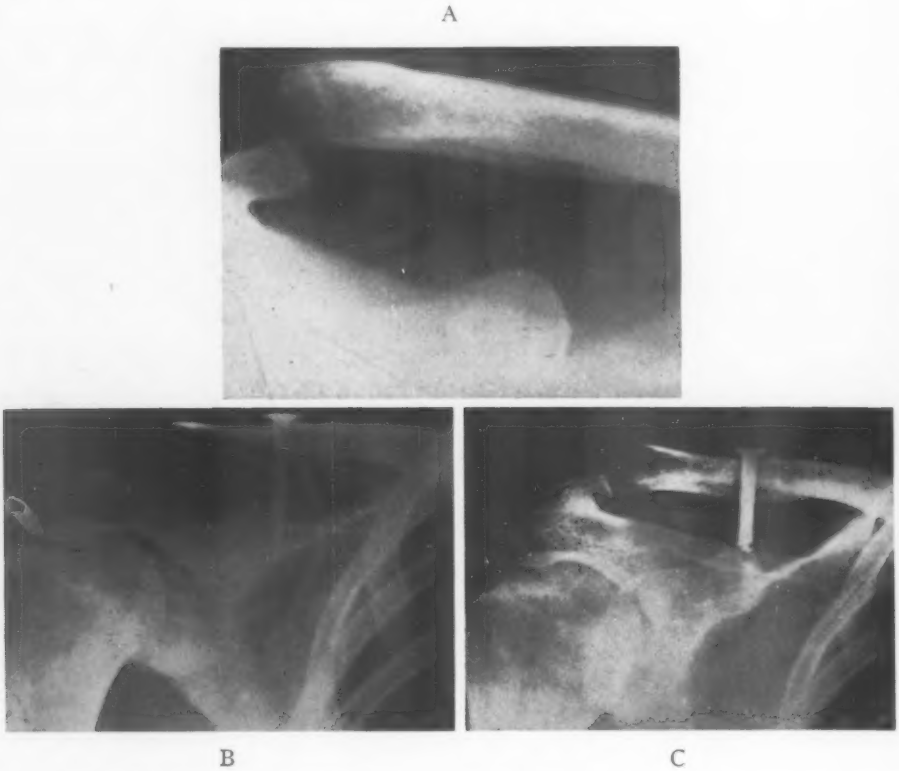


FIG. 6.—Case 7: R. H., electrical engineer, age 23.

A. Failure of pressure dressing.
B. Screw reduction.
C. Four years and 2 months result. Reduction maintained despite breaking of screw. Patient accepted by navy. A4—E4—F4.

tackle in a football game. This was another tall, muscular individual. Tight adhesive strapping for two weeks failed to maintain reduction and caused extreme skin irritation. Operation was performed, 12–20–1941, with the new flanged screw. Excellent reduction was secured (Fig. 6B), and he returned to full (clerical) work eight hours a day the second day after operation, without a sling. He dressed and took care of himself from the day of operation but he noticed a slight restriction of motion in reaching across his chest or behind his back. Ten weeks after operation, while lifting a 75-pound weight, he felt the screw snap and immediately found himself with a complete range of motion. In 1944, he was accepted for service in the navy. Examination, 2–22–1946,

revealed no pain, tenderness, limitation of motion, weakness or deformity. Roentgenograms (Fig. 6C) show the broken screw, but reduction well-maintained and considerable bony callus in the healed coracoclavicular ligaments.

COMMENT: In this case the screw obviously interfered to a slight extent with full range of motion in the acromioclavicular joint until the screw broke. When, as here, the screw restricts motion, it should be removed at eight weeks. Four years and two months result: A4—E4—F4.

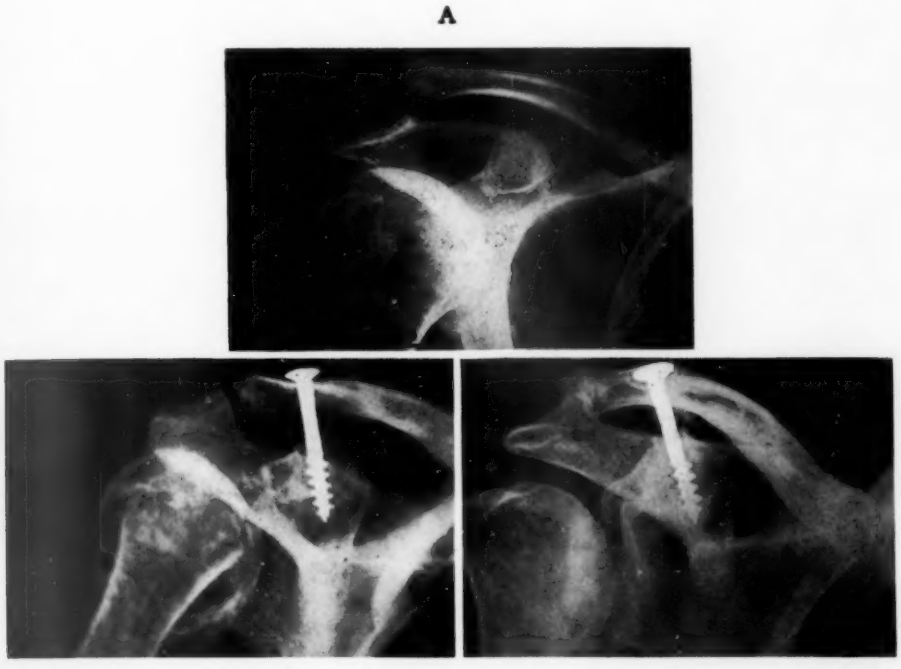


FIG. 7.—Case 8: N. W., housewife and business woman, age 47.

A. Firmly adherent acromioclavicular dislocation and frozen shoulder.
B. Fracture of humerus following remanipulation by another surgeon seven weeks after original surgery. Note that screw did not pull in spite of force applied.
C. Four years and 2 months result. No recurrence of acromioclavicular dislocation. A4—E4—F4. Surprisingly good function with malformed head of humerus.

Case 8.—N. W., at the age of 47, was knocked down by an automobile more than two months before she came for treatment. During this time she had been wearing a pressure dressing and receiving physiotherapy three times a week. Examination revealed a very thin, extremely apprehensive woman who seemed on the verge of a nervous breakdown. There was a persistent severe dislocation of the right acromioclavicular joint, the tip of the clavicle riding above the acromion (Fig. 7A). It had become fixed in this position by adhesions and could not be reduced. All motions in the shoulder joint were severely limited by adhesions and attempts at passive motion elicited intolerable pain. At operation, 1–13–1942, the adhesions about the frozen shoulder joint were broken up by manipulation under general anesthesia. The acromioclavicular joint was exposed, adhesions severed by sharp dissection and complete reduction was secured. This was

maintained by the insertion of a flanged vitallium screw in the usual manner. One week after operation I was called to active army duty and lost control of the patient. Seven weeks after the initial surgery, manipulation under anesthesia was again performed by another surgeon to free the shoulder joint which had refrozen. This, unfortunately, resulted in a fracture through the rarefied surgical neck of the humerus (Fig. 7B) although reduction of the acromioclavicular dislocation was maintained by the screw. The patient was discharged three weeks later, but for eight months she returned to

A

B

C

FIG. 8.—Case 9: M. C., laborer, age (?) (Courtesy of Dr. D. H. Maunz, Bradford, Pa.)

A. Preoperative film.

B. Screw inserted well through both cortices of coracoid.

C. Five months result. Note maintenance of reduction despite heavy work and extensive callus formation in coracoclavicular ligaments. A4—E4—F4.

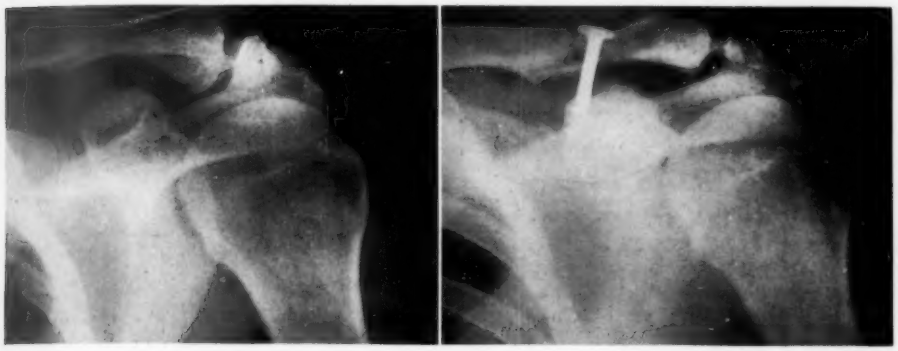
the clinic daily for physiotherapy. When seen four years and two months after operation, this woman had changed from a pain-ridden cripple to a cheerful housewife. The acromioclavicular joint remained reduced, but there was restriction of motion in the shoulder joint due to the fracture of the humerus previously mentioned. She could reach

well behind her back, to the back of her neck and the top of her head. Roentgenograms (Fig. 7C) show reduction of the acromioclavicular joint with the screw encapsulated by bone. The humeral fracture has healed, with a deformed head.

COMMENT: This case was an old acromioclavicular separation complicated by a badly frozen shoulder and a subsequent fracture of the surgical neck of the humerus incurred during treatment. Four years and two months result of the acromioclavicular repair: A4—E4—F4.

Cases of Other Surgeons (based on personal communication):

Case 9.—(From Dr. Daniel H. Maunz, Bradford, Pa.) M. C., a manual laborer, 12-14-1941, suffered a complete acromioclavicular dislocation (Fig. 8A). An attempt to insert the screw in the coracoid, 1-2-1942, with patient sitting upright, failed. On 1-6-1942, with patient lying on his back and under general anesthesia, open reduction of the acromioclavicular separation was accomplished, the coracoid was exposed and the



A B

FIG. 9.—Case 10: N. B., laborer, age (?) (Courtesy of Dr. G. K. Coonse, Boston, Mass.)
A. Four months old acromioclavicular dislocation.
B. Six months result. Dislocation over-reduced. A4—E4—F4.

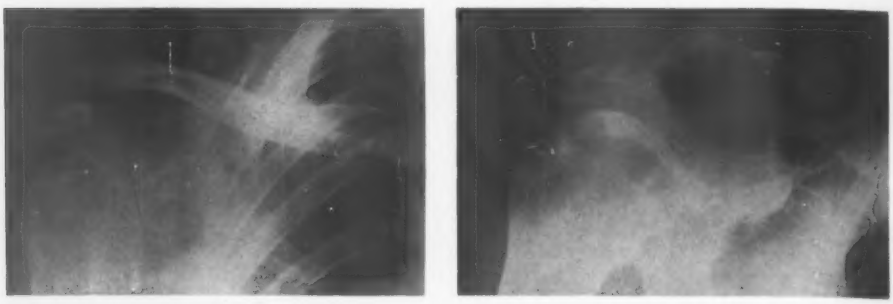
screw inserted under direct vision (Fig. 8B). Latest roentgenograms (Fig. 8C), taken more than three months after operation, show maintenance of excellent reduction, no absorption about the screw threads and a mass of fresh callus extending from coracoid to overlying clavicle. When last seen by Doctor Maunz in June, 1942, five months after operation, the patient was doing heavy work and had no complaints. This patient died of other causes some two years ago.

COMMENT: Note that the screw penetrated both cortices of the coracoid and that abundant callus formed in the region of the torn ligaments. Five months result: A4—E4—F4.

Case 10.—(From Dr. G. Kenneth Coonse, Boston, Mass.) N. B., a manual laborer, presented an acromioclavicular dislocation that was more than four months old (Fig. 9A). Screw reduction was performed in April, 1941, and the patient returned to fairly heavy labor two months later. At the last examination six months after operation Doctor Coonse reported "a very satisfactory end result. At present time there is less prominence on the affected side than on the normal side." Roentgenograms (Fig. 9B) taken one month postoperative show reduction maintained by screw in good position.

COMMENT: This was an old persistent acromioclavicular separation successfully treated with screw suspension. Note again that the screw was made to penetrate both cortices of the coracoid, and that callus formed in the ligaments. Six months result: A4—E4—F4.

Case 11.—(From Dr. F. W. Slobe, Chicago, Ill.) "H. H., age 59, was injured 10–1–1945, the outer end of the clavicle projecting into the muscles and skin posteriorly (Fig. 10A). He was operated upon 10–4–1945. Recovery was uneventful, and he was singularly free from pain and discomfort during convalescence. He returned to his work as a teamster six weeks later. Roentgenograms (Fig. 10B) taken in December, 1945, show some upward displacement, with the screw pulled out partially." Five months after operation "there has been no increase in the deformity as indicated on his last roentgenograms. He has very little discomfort in the shoulder and has full range of motion.



A B

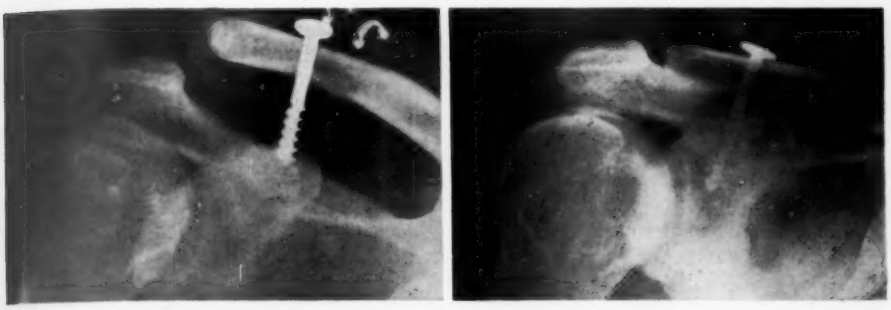
FIG. 10.—Case 11: H. H., teamster, age 59. (Courtesy of Dr. F. W. Slobe, Chicago, Ill.)
A. Complete acromioclavicular dislocation.
B. Five months result. Screw not inserted deeply enough. Excellent function. A3—E4—F4.

COMMENT: This was an industrial case and he has made no claim for compensation which, I think, is quite indicative of how he feels about the result. I feel also that functional impairment is minimal.

Case 12.—(From Dr. F. W. Slobe, Chicago, Ill.) "A. S., age 43, 1–22–1946, was injured in an automobile accident and suffered a complete acromioclavicular dislocation on the right side. We did not see the patient until a few days later, when he was sent to the hospital and was operated upon. It appeared that we had a good fixation and reduction in the operating room, but roentgenograms taken the following day showed that the screw had only contacted part of the coracoid (Fig. 11A), so a few days later the procedure was performed again, this time being checked by an anteroposterior roentgenogram. This worked very well, and we obtained an excellent reduction (Fig. 11B)."

COMMENT: These two cases illustrate the superiority of roentgenograms over fluoroscopy as a means of checking screw position during operation, as well as the necessity of sinking the screw firmly into the coracoid so that its threads grasp the under cortex of that bone. Five months result in Case 11: A3—E4—F4. It is too early to give an end-result in Case 12.

Case 13.—(From Dr. W. F. Cotting, Boston, Mass.) "A young man fell off a traveling crane, and I was able to insert one of your screws and obtain a very excellent result. He was immobilized in a double sling for about two weeks, and within four weeks had normal motion. It is now 12 weeks since he was injured, and he shows today perfectly normal shoulder motion with no loss of function." Neither the roentgenograms nor the patient can be located.



A B

FIG. 11.—Case 12: A. S., occupation (?), age 43. (Courtesy of Dr. F. W. Slobe, Chicago, Ill.)

A. First attempt at reduction using fluoroscope. Screw not inserted deeply enough.
B. Reoperation, using roentgenologic check-up. Screw solidly implanted. Case too recent for end-result.

FIG. 12.—Case 17: (Courtesy of Dr. S. A. Bernstein, Brooklyn, N. Y.) Four-year result. A4—E4—F4.

Case 14.—(From Dr. W. F. Cotting, Boston, Mass.) "I operated upon G. M., 10-25-1941. He was a truckdriver and made a good recovery. He had normal range of motion in the shoulder and no appreciable mobility at the acromioclavicular joint. He made his last postoperative visit on 11-17-1941. I heard no more from him until 3-9-1942. Examination then showed a foreign-body reaction manifested by some local tenderness and inflammation. On 3-16-1942 (five months after the original operation) I

removed the screw under local anesthesia, and last saw him postoperatively on 4-6-1942. He was back at work and had no symptoms. The wound was fully healed and he had normal motion and function. I have been unable to locate the roentgenograms."

COMMENT: Removal of the screw in Case 14 apparently did not weaken the repair. Although roentgenograms in both the foregoing cases can not be located, reliable clinical examination indicates the end-results at three months in Case 13 and five and one-half months in Case 14 as: A4—E4—F4.

Cases 15 and **16.**—(From L. E. Gilje, Capt., M. C., U. S. N., Chief of Surgery, U. S. Naval Hospital, Bethesda, Md.) "I used the acromioclavicular screw on two cases. In the first case, the screw broke loose from the coracoid process after about six to eight weeks and had to be removed because it was producing pressure on the surrounding area. In the second case, the screw was utilized to fix the distal end of the clavicle to the coracoid process and a portion of the short head of the biceps was brought up and anchored to the clavicle. The screw was only left in place until the tendon of the short head of the biceps was firmly adherent to the clavicle."

COMMENT: It is regrettable that the roentgenograms in these two cases are unavailable. Also, there is no indication as to when these two patients resumed heavy work. However, the end-result in the first case was an obvious failure and that in the second case, although apparently successful, is immaterial since the screw was used as an adjunct in the operation and not depended on for sole support.

Case 17.—(From Dr. S. A. Bernstein, Brooklyn, N. Y.) "I operated upon my patient 4-6-1942. He had a full range of motion four weeks after the operation. Examination 3-22-1946: Patient states that the right shoulder does not bother him except for a slight grating noise on certain motions of this joint. He uses the arm very freely and does not spare it. He was discharged from the army after two and one-half years of service in an engineer outfit. His discharge was not predicated on any disability. The right shoulder shows no elevation of the outer end of the clavicle as compared with the left. There is a full range of active motion in all directions. No weakness of the muscles of the right shoulder girdle. Good power of both hands. There is no tenderness over the outer end of the clavicle." Roentgenograms (Fig. 12) show that the screw has not moved, and that reduction of the acromioclavicular joint has been maintained.

COMMENT: Two and one-half years of service in an engineer outfit during the recent war is a good test of any method used in repairing an acromioclavicular dislocation. Four-year end-result: A4—E4—F4.

SUMMARY

Detailed end-results have been presented of 17 cases in which a suspension screw was used by seven different surgeons in the treatment of acromioclavicular dislocation. Eight of these are the first consecutive cases in which the operation was used. Modifications of the operative technic are presented.

CONCLUSIONS

The long-term end-results of screw suspension in the treatment of acute and chronic dislocation of the acromioclavicular joint have been very satisfactory. In addition, disability of the patient has been minimized, early

mobilization of the extremity has been assured, and convalescence shortened. Experience has shown that dangers inherent in the operation are negligible.

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ISCHEMIC NECROSIS OF THE ANTERIOR CRURAL MUSCLES

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ISOLATED NONINFECTIVE GANGRENE involving the muscles of the anterior compartment of the lower leg is not a frequently encountered clinical entity. In 1942, Child[1] reported such a case following a simple fracture through the middle third of the tibia and fibula; and in reviewing the literature from 1850 to 1942, he could find only 14 cases of noninfective gangrene accompanying fractures of the lower leg, only one of which involved the anterior tibial artery alone.

With the advent of large orthopedic services in Army hospitals throughout the country, this condition of localized gangrene has been recognized more frequently. The failure to recognize and diagnose accurately the condition no doubt accounts for the small number of cases reported in the literature. Sirbu, Murphy and White[2] have reported four cases of ischemic necrosis of the anterior crural muscles. Two of these cases were associated with fractures of the lower leg, another case followed surgical repair of a defect in the anterior crural fascia, and the fourth case had no antecedent trauma other than participation in a long march. Recently, Horn[3] has reported two similar cases not associated with any acute trauma.

The etiology of this condition, of course, is a functional impairment of the anterior tibial vessels of a degree sufficient to produce gangrene of the anterior crural muscles. In the cases which are associated with fracture of the tibia or fibula, it seems logical to assume that the anterior tibial vessels may have been damaged irreparably at the time of the original injury, even though the fracture may show little comminution or displacement and the trauma producing the fracture may have been of a minor character.

Anatomically, there are several factors which may enhance the possibility of damage to the anterior tibial vessels in cases of trauma to the leg. The origins of the anterior and posterior tibial arteries are quite rigidly fixed by surrounding structures so that they are subject to injury not only by direct violence but also by force transmitted to the bifurcation of the popliteal artery from other parts of the leg. The anterior tibial artery passes to the front of the leg through a relatively small aperture above the upper border of the interosseous membrane. It is reasonable to assume that the vessel might be damaged by any trauma transmitted to this site. At this location, too, the vessel lies close to the medial side of the neck of the fibula, and might be traumatized easily by a jagged fragment of bone when the head and neck of the

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fibula are fractured. Finally, the boundaries of the anterior crural compartment are quite rigid structures; the thick deep fascia of the leg, the anterior intermuscular septum, the interosseous membrane, and the tibia and fibula rigidly enclose the tibialis anterior, extensor hallucis longus, extensor digitorum longus and peroneus tertius muscles. The anterior tibial vessels and the peroneal nerve enter this compartment and may be secondarily damaged by pressure produced by swelling within this tightly enclosed space.

In the absence of any acute trauma to the lower leg, the cause of the circulatory impairment of the anterior tibial vessels may be very difficult to determine. In one of the cases reported by Horn, a fibrosis of the media, adventitia, and periarterial tissue of the anterior tibial artery was found; and it was assumed that this fibrosis might be the result of repeated overwhelming demands made upon this vessel. Excessive walking and marching may have some direct relationship to circulatory disturbances in the anterior crural muscles.

The clinical aspects of this syndrome are well illustrated in the following case reports:

Case 1.—After returning from a night cross-country training flight on 25 October 1943, a 25-year-old Air Cadet noticed a gradual onset of severe cramp-like pain in his left lower leg as he walked the half mile distance back to his base. The muscles over the anterolateral aspect of the left lower leg became hard and painful to touch, but there was no redness or swelling. He entered a local station hospital the same night where a diagnosis of acute osteomyelitis was made, despite the fact he had no fever. Warm stupes were applied to the entire left leg. The following day, 26 October 1943, the patient was operated upon. A four-inch longitudinal incision was made over the anterolateral aspect of the proximal third of the tibia and eight drill holes were placed in the bone. No pus was encountered at time of operation. The wound was packed open with vaselined gauze. On 15 November 1943, an attempt was made to close this wound by secondary suture; but the wound failed to heal.

The soldier was admitted to this general hospital on 31 December 1943 for further treatment. On admission the soldier was afebrile. There was a small draining sinus over the anterolateral aspect of the proximal third of the left tibia and a slightly tender fluctuant area over the lateral aspect of the distal third of the tibia. There was complete paralysis of all the anterior crural muscles. Roentgenograms of the leg revealed slight periosteal reaction involving the distal third of the tibia.

On 5 January 1944 the soldier was taken to the operating room, where both the fluctuant area and the draining wound were explored. Necrotic muscle and tendon were found in both areas. The two small incisions were connected by a longitudinal incision extending from the level of the tibial tuberosity to the level of the external malleolus. The anterior crural fascia was incised, exposing the soft, friable, reddish-gray muscle bellies of the anterior crural muscles. All of these muscles were necrotic and were removed readily by finger dissection. The anterior tibial vessels were ligated; but it was noted that there was very little bleeding in these vessels. There was no palpable pulsation in the anterior tibial artery, and the lumen of the artery was almost completely obliterated. The large cavity remaining after complete removal of the anterior crural muscles was packed loosely with vaselined gauze; and the skin edges were kept from retracting by four mattress sutures of heavy silk, tied over bolsters. A long leg plaster encasement was applied.

The postoperative course was satisfactory. The temperature was elevated up to 100° F. for two days; and then the patient remained afebrile. The wound granulated in

rapidly, and there was never any evidence of true osteomyelitis of the tibia or fibula. Slight drainage continued from the scarred area, however, until 15 August 1943 (Fig. 1A). On this date the major portion of the scarred area was excised, and the adjacent skin edges undermined and approximated. Healing was prompt and complete following this surgery.

The patient was ambulatory at this time, wearing a spring-toe brace to provide extension of his foot. To enable the patient eventually to discard this brace, the posterior tibial tendon was transplanted on to the dorsum of the left foot on 10 November 1944. Three months later, he was able to walk well without his brace. The tendon transplant functioned quite satisfactorily, permitting about 25° of active motion in the ankle joint and enabling the soldier to extend his foot to a right angle (Fig. 1B).

FIG. 1A

FIG. 1B

FIG. 1.—Case 1: (A) Lateral view of lower leg, six months following excision of all the anterior crural muscles because of acute ischemic necrosis. (B) Double exposure of same leg to show range of active motion in ankle ten weeks following transplantation of the posterior tibial tendon onto the dorsum of the foot. The depressed scar seen in (A) has been excised.

Case 2.—A 33-year-old male, working in the Army for the American Red Cross, sustained compound comminuted fractures of both lower legs on 13 March 1943. He was struck by a hit-and-run civilian driver and thrown against the rear bumper of his own car. He was admitted at once to the station hospital of a local Army Air Base. There was a compound comminuted fracture through the middle third of the right tibia and fibula, with only a small puncture wound leading down to the fracture site. This fracture was treated by closed reduction and application of a long leg encasement. On the left, there was a severely comminuted fracture through the proximal third of the tibia and fibula, with loss of skin over the anterior aspect of the leg from a point two inches above the ankle to within four inches of the knee, exposing a portion of the crest and anteromedial surface of the tibia.

At the station hospital, the extensive wound of the left leg was débrided; the fracture of the tibia was reduced; and two of the small comminuted tibial fragments were

held in alignment with a single loop of stainless steel wire. A large pedicle of skin was elevated from the lateral side of the leg and swung across the anterior aspect of the leg in an attempt to cover the exposed tibia. The entire denuded area was covered with vaselined gauze, and a long leg encasement applied.

On 22 March 1943, the patient was admitted to this general hospital for further care. On admission, the patient's general condition was excellent, and there was no elevation of temperature. Both long leg encasements were badly blood-stained, and the left leg encasement was somewhat softened by drainage and very malodorous.

(In order to make the clinical course more clear, this discussion will be limited to the treatment of the left leg. It is of interest, however, to note that the fracture of the right tibia did not unite, and a bone-grafting operation was performed six months after the injury to obtain a solid bony union. At the present time there is no disability referable to the right leg).

Soon after admission to the hospital, the encasement on the left leg was bivalved and the wound inspected. There was found a large granulating wound occupying the major portion of the anterior aspect of the lower leg, covered in part by necrotic skin. The pedicle of skin which had been elevated from the lateral aspect of the leg was completely gangrenous. There was a moderate amount of purulent drainage. The crest and anteromedial surface of the tibia was exposed in the distal two-thirds of the bone; and the fracture site, as well as the loop of wire, were also exposed. There was a deep ulceration over the dorsum of the foot, measuring approximately two inches in diameter and covered with necrotic skin. There was complete paralysis of all the extensor muscles of the foot and ankle. The necrotic skin and the wire loop were removed. A posterior splint was fashioned to permit adequate dressing of the wound; and azochloramid (N-N'-dichloroazodicarbonamidine) dressings were applied.

Guillotine amputation of the left leg was recommended, but this amputation was not considered an emergency procedure since there was no evidence of any detrimental systemic effect arising from the well-localized infective process in the leg. It was felt that amputation might be delayed until the outcome of the fracture of the right lower leg appeared more certain. Furthermore, it was believed that a delay in amputation might permit eventual salvage of a stump below the knee. The patient himself was very anxious not to have the left leg amputated.

The wound was treated with daily dressings of azochloramid. Since it soon became obvious that all of the anterior crural muscles had undergone ischemic necrosis, on 12 April 1943 all of these muscles were removed, exposing the entire anteromedial and lateral aspects of the tibia. The patient remained afebrile following this procedure, nor did he ever manifest even so much as a degree of fever following any of the subsequent operations on the left leg.

By 8 June 1943, the wound was clean and covered with healthy granulation tissue. The distal two-thirds of the tibia was still exposed; and it was evident that this exposed bone could not be salvaged. Consequently, this portion of the tibia was removed, leaving only the posterior cortex of the bone (Fig. 2A). Seventy-five small pinch-grafts were applied to the granulating area on the lateral aspect of the leg. All of the exposed bone was now on a level with the granulation tissue, permitting granulations to grow over the bone.

On 9 July 1943, the entire wound, including the exposed tibia, was covered with thin scar, and there was no longer any drainage. The thin scar was excised and replaced by a split-thickness skin graft over an area measuring nine and one-half inches by four inches. There was a 100 per cent "take" of this skin graft (Fig. 2C and D).

By 3 August 1943, the fracture of the tibia was well united, but further immobilization in a long leg encasement with a walking iron was carried out. This encasement was replaced by a long leg caliper brace on 8 December 1943.

The lateral edge of the tibia for a distance of about three inches in its middle third became exposed, and there was slight drainage from this region. On 4 February 1944,

a portion of this exposed edge of bone was removed, and multiple drill holes were placed through this area to permit granulation tissue to grow up and cover the bone. By 14 March 1944, the bone was completely covered with epithelium again, and there was no drainage. The fracture of the tibia was solidly united, and there was a range of motion in the knee of from 180° extension to 90° flexion. On 13 July 1944, a small sequestrum was removed from the lower third of the tibia; and this small sinus tract promptly healed.

FIG. 2A FIG. 2B

FIG. 2.—Case 2: (A) Lateral and anteroposterior roentgenograms of the left leg three and one-half months after injury. The portion of the tibial shaft which was not covered by skin or granulation tissue has been removed, leaving only the posterior cortex of this bone in the middle and lower thirds.
(B) Lateral and anteroposterior roentgenograms of the left leg two years after injury. There has been considerable hypertrophy of the segment of posterior tibial cortex in the middle and lower thirds; and this portion of the bone has been the site of an old chronic osteomyelitis.

The patient was discharged from the hospital on 22 September 1944, wearing a short caliper brace on the left leg to guard against fracture (Fig. 2C). There was 10° of active and passive plantar flexion at the ankle and 10° of passive dorsiflexion; there was no active extension of the foot. The ankle joint was not painful with walking.

A recent letter from this patient (dated 6 April 1946) states that the left leg has never hampered his activities as director of a Veterans' Information Center. He is able to walk as much or as far as he wishes, he drives his own car, and he finds dancing a pleasant pastime. He still wears the short leg caliper brace, but he feels that the brace

causes him much less trouble than would an artificial leg. He does not wear the brace all the time while at home. From 21 May to 6 July 1945, a large pedicle flap along the medial surface of the calf was elevated and transferred in three stages to replace the skin graft over the left tibia. This flap healed well and now provides a better covering for the tibia.

Case 3.—A 21-year-old Army sergeant was wounded in action by enemy mortar shell fire in Italy on 15 April 1945. He sustained multiple lacerations of the right lower extremity and a small "chip" fracture of the anterior aspect of the distal end of the tibia. His wounds were débrided and a plaster encasement applied in an evacuation hospital. On 18 April 1945, he was admitted to a general hospital in Italy. At this hospital it was noted that he was unable to actively extend his foot, and there was hypesthesia over the lateral aspect of the foot. An attempt was made to close all the wounds by secondary suture. All of the wounds healed except one on the anterolateral aspect of the middle third of the lower leg, and there was considerable purulent drainage from this area.

FIG. 2C

FIG. 2D

FIG. 2.—(C) Front view of both legs one year and six months after injury, showing the type of short caliper brace worn to protect the left tibia against fracture.

(D) Side view of the left leg one year and six months after injury. Note the extensive loss of both soft-tissues and bone in the distal two-thirds of the leg. The large defect has been covered by a split-thickness graft. One year later, this graft was removed and replaced by a pedicle flap.

On 27 May 1945, this unhealed wound was explored, and the muscle in the depths of the wound was found to be necrotic. The wound was extended by an incision the length of the anterior crural compartment. All of the anterior crural muscles were found to be necrotic, and all of these muscles were removed. The wound was packed open with vaselined gauze, and a plaster encasement applied.

On 28 September 1945, the soldier was admitted to this general hospital on the neurosurgical service for further treatment of his peroneal palsy. On examination, it was obvious that no neurosurgery was indicated. The peroneal muscles were functioning, but all the muscles in the anterior crural compartment were replaced by a depressed scar extending almost the entire length of the lower leg (Fig. 3A and B).

Because of the presence of several small excoriations over the lower leg, surgery was delayed until 14 November 1945. On this date, the tendons of the tibialis posticus and peroneus longus muscles were transplanted on to the dorsum of the foot. By 26 February 1946, the patient was able to use the transplanted tendons quite well and could walk without a brace. He was discharged from the Army on a certificate of disability.

Discussion.—These three cases illustrate the clinical course of an ischemic necrosis of the anterior crural muscles. In Case 1 there was no obvious pre-

Fig. 3A Fig. 3B

Fig. 3.—Case 3: (A) Side view, and (B) front view, of the right leg, six months after injury, showing the depressed scar which remains after surgical removal of all the muscles in the anterior crural compartment. There are multiple smaller scars over the entire leg which are the result of superficial lacerations by shrapnel fragments. Active extension was restored to the foot by transplantation of the posterior tibial and long peroneal tendons.

cipitating trauma, and there was no evidence of any peripheral vascular disease elsewhere in the patient. It cannot be denied that an embolus may have caused the rather sudden obliteration of the anterior tibial artery; but this is difficult to believe in the absence of clinical evidence of any abnormality in the cardiovascular system. Unfortunately no microscopic examination was made of the anterior tibial vessels themselves, although the gross appearance of the vessels at time of operation closely resembled the description given by Horn in one of his cases. Pathologic examination of tissue removed at the time of

operation in all three cases revealed the same picture of necrosis of skeletal muscle with fragmentation and dissolution of individual muscle fibers. No cause for the necrosis was apparent from a microscopic examination of the muscle tissue removed. It appears obvious, of course, that a traumatic thrombosis of the anterior tibial artery produced the ischemic necrosis found in Cases 2 and 3.

In Case 2, the correct diagnosis soon became obvious because of the extensive loss of skin overlying the anterior crural compartment. The correct diagnosis in the other two cases, however, was not made until the anterior crural muscles were explored surgically; in Case 1 this was two months after onset of symptoms, and in Case 3 it was one month after injury. A more prompt recognition of the condition with the institution of measures directed toward restoration or improvement of local circulation in the lower leg might prevent, or at least reduce, the extensive gangrene of muscle tissue. Lumbar sympathetic blocks are valuable in almost any case of arterial spasm. If these are not successful, surgical exploration of the anterior tibial vessel should be considered, with either periarterial sympathectomy or arteriectomy being done to improve the collateral circulation. Extensive fasciotomy of the anterior crural fascia might be assumed to relieve the increased pressure within the closed compartment.

If any surgical procedure is performed on a case of this type, extreme care must be taken not to introduce any pyogenic organisms, since once such organisms have been inoculated into a bed of necrotic muscle (as was done in Case 1), the infection cannot be controlled until all the necrotic tissue has been removed.

After the anterior crural muscles have been damaged irreparably, tendon transplantation, as illustrated in Cases 1 and 3, may restore adequate extension to the foot and enable the patient to walk without a brace. Either the posterior tibial muscle alone, or preferably this muscle in combination with one of the peroneal muscles, may be used. Arthrodesis of the ankle joint, or even arthrodesis of the subastragalar joint, should not be necessary in a case of this type.

SUMMARY

1. Localized ischemic necrosis of the anterior crural muscles is an infrequent complication of injuries to the lower leg.

2. Three cases of localized ischemic necrosis of the anterior tibial muscles are presented. Two of these were secondary to traumatic occlusion of the anterior tibial vessels; but the etiology in the third case could not be determined.

3. If this condition is diagnosed promptly, measures may be instituted to prevent complete devitalization of all the muscles in the anterior crural compartment.

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OBSTRUCTIVE LESIONS OF THE SMALL INTESTINE AND SIGMOID DUE TO IRRADIATION

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THE INTENT OF THIS REPORT is to emphasize to those not closely associated with a Department of Radiology, the late clinical picture of obstruction due to irradiation.* This group of five cases being reported received irradiation for carcinoma of the corpus, cervix and ovary, and, who later, showed symptoms of obstruction.

The complaints of those patients who develop lesions in the low sigmoid and rectosigmoid after irradiation are: Abdominal cramp-like pains, associated with frequent small liquid stools, mucus and blood. Later, when the acute phase of hyperemia and mucosal edema is replaced by cicatricial contraction, physical signs of low sigmoid obstruction are present.

The terminal ileum is frequently in the low pelvis, and in the area of active irradiation. Therefore, the symptoms of complete or incomplete low small intestinal obstruction often appear earlier than obstruction of the low sigmoid.

It seems important to advance the thought that a patient who has received irradiation to the pelvic region and later complains of abdominal pain, change in bowel habit, nausea and vomiting, does not necessarily have a recurrence or extension of the original disease. There may be a stenosing and partially obstructing lesion, the late-result of irradiation. This may be corrected by the proper surgery, with the outlook much more favorable.

Some obstructive lesions of the sigmoid regress, and the normal lumen is restored. This follows, at times, as the result of a proximal defunctionalizing colostomy. If the obstruction regresses, it can be due only to a lessening of the infection and the disappearance of the edema, which is caused by the constant trauma of the bowel content. Scar tissue could not be expected to regress.

The following five case histories are presented and the surgical treatment described:

CASE REPORTS

Case 1.—Mrs. H., age 63, was admitted to the hospital 3-8-'35. Chief complaint was postmenopausal bleeding. Tissue section of the diagnostic curettage specimen proved the lesion to be adenocarcinoma of the corpus uteri. Intra-uterine irradiation for a total of 3,000 mg. h. was given. Thirty-five days after the completion of the irradiation, an abdominal total hysterectomy was performed. At this time, an area of 6 cm. of the sigmoid, found in intimate contact with the posterior wall of the uterus, was thickened and edematous. Appendices epiploicae in this area were firmly attached to the serosa of the

* Irradiation under the direction of John F. Hynes, M.D., Director of Carpenter Memorial Clinic, the Memorial Hospital, Wilmington, Delaware.

sigmoid. The patient complained within two weeks after irradiation of rectal pain, and tenesmus, with the passage of mucus and blood. These symptoms improved, but never entirely disappeared. She was readmitted to the hospital 12–27–'39. This was four and one-half years after irradiation. The clinical picture was that of large-intestinal obstruction. The abdomen was markedly distended and asymmetric. Persistent vomiting of duodenal and high jejunal fluids. At operation, under spinal anesthesia, the large intestine was found to be dilated and distended to the area in the low sigmoid described above, found at the time of operation. A distinct mass was palpable. A cecostomy was established. Cecostomy was closed 1–5–'40. She recovered, and later developed a rectovaginal fistula. This patient, now age 74, is living and well. The fistula has closed. There is no evidence of the primary disease.

Case 2.—Mrs. T., age 35, was treated for a pathologically-proven carcinoma of the cervix. She received 2,700 r. through four fields—two anterior and two posterior. The areas were alternated, giving 300 r. a day to two fields. External irradiation was begun 4–28–'41. On 5–12–'41, she complained of abdominal pain and diarrhea, and was readmitted 6–7–'41. On 6–30–'41, she received 3,000 mg. h. to the cervix. On 8–15–'41, which was three and one-half months after treatment, she was readmitted and had an abdominal exploration. At this time, she had paroxysmal, cramp-like abdominal pain, with visible peristalsis.

Operation.—8–17–'41: The terminal ileum, from a point 6 cm. proximal to the cecum, was found to be fixed to the right lateral pelvic wall. It formed a hard, and indurated, fixed mass. There was a 6-cm. area of complete necrotic ileum through which some leakage had occurred. The ileum, for 30 cm. proximal to this area, had edematous and thickened walls. A resection of 30 cm. of the terminal ileum was undertaken, with an end-to-side ileocecostomy. A Witzel enterostomy 30 cm. proximal to the anastomotic site was established. The wound sloughed, and there was no attempt at healing in the zone of irradiation. The patient died 11–1–'41. This was two and one-half months after operation. Death was due to hemorrhage from the deep epigastric artery.

Case 3.—Mrs. O'B., age 30, had an abdominal exploration in Pennsylvania previous to her admission to this hospital. Exploration, only, was made at that time. There was a large agglutinated mass which filled the entire pelvis. Numerous areas in the great omentum, which were secondary implants from a primary papillary carcinoma of the ovary. The peritoneal cavity contained 2,000 cc. of free fluid, which was aspirated. Abdominal paracentesis was done, in this same hospital, on four successive occasions. An average of 1,500 cc. of fluid was removed each time.

This patient was then admitted to the Memorial Hospital, for radiation therapy. External irradiation was completed 5–16–'35. There was a definite reduction in the abdominal mass. The ascites had not recurred. She had gained eight pounds. A second cycle to the right pelvis, of 1,200 r. was administered through an anterolateral and posterior pelvic field. Due to reduction in the size of the abdominal mass, increased mobility, and the absence of recurrent ascites, exploration was decided upon. On 5–27–'36, an abdominal total hysterectomy was performed. There was a large cystic mass between the leaves of the left broad ligament and also in the prevesical space. The pathologic diagnosis was papillary cyst adenocarcinoma of the ovary, with metastases. On 6–16–'39 a firm mass was palpable in the rectovaginal septum. Celiotomy was done, under direct vision. Radon seeds were implanted.

The patient was readmitted to the hospital 7–12–'41. She complained of abdominal fulness, recurring cramp-like pains, nausea, and vomiting. The picture was one of low, small intestinal obstruction. On operation, 7–16–'41, the following findings were noted:

There was complete obstruction at the ileocecal junction. The terminal ileum was firmly agglutinated to the posterior parietal peritoneum and to the right lateral bladder wall. The fixation and angulation produced the obstruction. The diameter of the

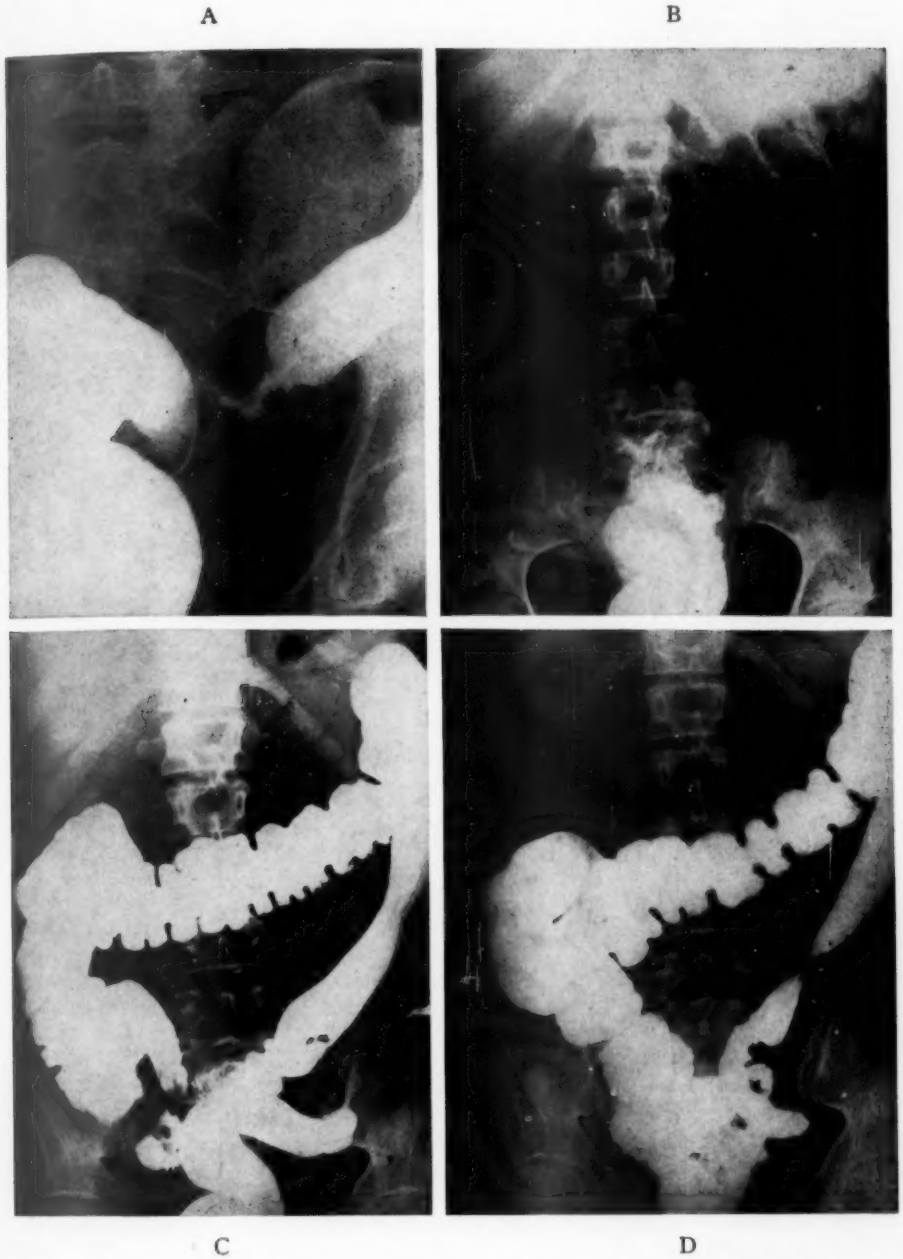

FIG. 1.—(A) Case 4: Barium enema, 11-23-40, showing an obstructive narrowing in the low sigmoid six months after beginning of therapy.

(B) Case 4: Further progress in the constricted area ten days later (12-3-40).
(C) Case 4: Barium enema six weeks after closure of colostomy (9-3-'41).
(D) Case 4: Post evacuation enema (9-3-'41).

terminal ileum was four times that of normal. The walls were thickened and edematous. These changes were seen for many feet proximal to the area of obstruction. The small intestine contained, on decompression, 2,000 cc. of fluid. A lateral ileocolostomy was established after decompression. The ileum, 30 cm. proximal to the point of obstruction, was anastomosed to the transverse colon. The patient was discharged 8–3–'41, and died 8–6–'44 of a further extension of the original disease, six years and three months after the original irradiation.

Case 4.—Mrs. S., age 37, was admitted to the hospital 5–20–'40. The following treatment for carcinoma of the cervix was given: Deep therapy through four fields, two anterior, and two posterior; 3,000 r. to each field. Radium 4,500 mg. h. to cervix 5–22–'40. On 5–28–'40, 750 mg. h. and a like amount 5–20–'40.

She was readmitted 11–19–'40. For four weeks she had complained of cramp-like abdominal pain and a mucus diarrhea, with blood at times. There was a palpable mass in the L.L.A.Q., medial to the inguinal ligament. A barium enema showed a persistent filling defect in the pelvic sigmoid. The lumen was greatly diminished.

Her complaints persisted under bed rest, a low residue diet and warm colonic irrigations.

Abdominal exploration on 12–4–'40. This was eight months after the completion of irradiation. There was a sharply defined area of the sigmoid, 12 cm. proximal to the rectosigmoid junction. This area was 8 cm. in length; the sigmoid wall at this point was thickened and edematous. No lumen could be demonstrated. The walls of the sigmoid, for 12 cm. proximal to the sharply defined area, were slightly thickened and edematous. This was due to the distal obstruction. A temporary colostomy was established 20 cm. above the constricted area. She was discharged 1–5–'41. The abdominal cramp-like pain and diarrhea had entirely disappeared. She had gained weight.

She was readmitted 3–4–'41. A barium enema showed almost complete restoration of the lumen. The colostomy was closed. A barium enema one month later showed but a slight narrowing of the lumen. There were no abdominal complaints. She was examined 6–12–'46, there was no evidence of any recurrence of disease.

Case 5.—Mrs. H., age 47, was admitted to the hospital, 9–1–'44, and treated for carcinoma of the cervix. She received 4,500 mg. h. to the cervix. She was readmitted, 9–15–'44, complaining of lower abdominal pain, with diarrhea. A tender mass was palpable in the left vaginal fornix. The impression was that of an acute exacerbation of a chronic salpingitis due to irradiation. She improved under treatment, and was discharged 9–21–'44. She was readmitted 3–20–'45. The complaints at this time were: Cramp-like lower abdominal pain, frequent liquid stools, with blood and mucus. Weight loss of 13 pounds in three weeks, and occasional vomiting. There was moderate fullness in both lower abdominal quadrants.

A barium enema, 4–4–'45, showed an obstructive area slightly proximal to the rectosigmoid junction. The diameter of the bowel at the point of maximum constriction was less than 1 cm. The obstructed area was constant and would not dilate under hydrostatic pressure.

Operation.—4–16–'45: The sigmoid, left colon and a portion of the transverse colon showed the effects of distal obstruction. The colon was dilated, with edematous walls. The lumen contained many hard balls of fecal matter. About 2 cm. proximal to the rectosigmoid junction there was a hard, firm mass in the sigmoid. It was 12 cm. in longitudinal extent. The liver, uterus and adnexae were normal. A temporary, diverting right transverse colostomy was established.

Despite daily colonic irrigations from above-down, and from below-up, it was impossible to clear the colon. The patient complained of severe, recurrent, cramp-like pain in both lower abdominal quadrants. Frequent narcotics were required.

A second operation, a left inguinal colostomy, was performed on 5–18–'45. Through

a lower left rectus incision, it was possible to have the low sigmoidal lesion under direct vision. It began at the rectosigmoid junction. The walls were edematous, thickened and rubber like. This area extended upward for 4 cm. At this point there was a

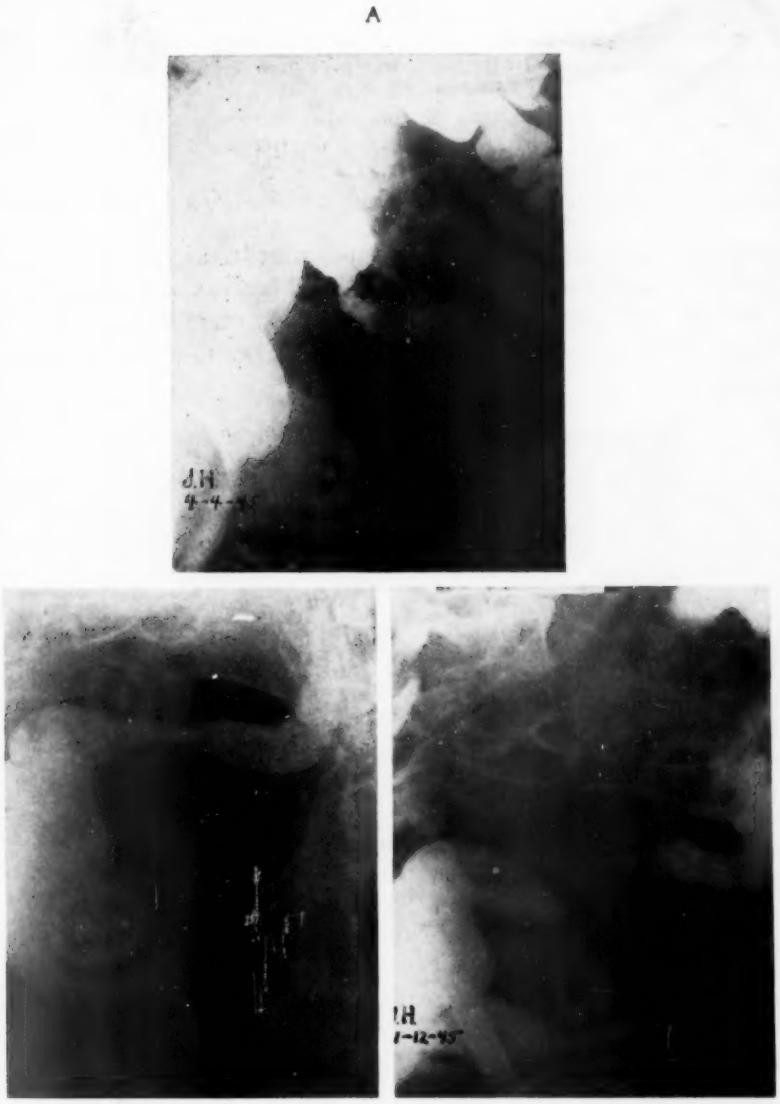

FIG. 2.—(A) Case 5: Barium enema seven months after radiation (4-4-'45).
(B) Case 5: Barium enema (7-10-'45).
(C) Case 5: Three months later. There is still no change (11-12-'45)

hard, firm mass extending proximally for a distance of 8 cm. The mass was not intraluminal, but consisted of inflammatory thickening in the bowel wall and the mesentery. From the most proximal point of the mass, the epiploic appendices were thickened and

red for a distance of 30 cm. The sigmoidal mass was firmly agglutinated to the posterior parietal peritoneum in the right iliac fossa. The posterior surface of the right broad ligament was agglutinated to it, as were the numerous coils of small intestine by a cartilaginous-like induration. There was no evidence of lymphatic extension of the original pathology. (Squamous cell carcinoma of the cervix.)

With frequent injections of mineral oil and irrigations from the right transverse colostomy to the left inguinal colostomy, this portion was finally cleared of hard, firm lumps, consisting of dehydrated barium and fecal matter.

Barium enema ten months after radiation, and three months after a temporary diverting transverse colostomy, and two months after the left inguinal colostomy, showed no change in the filling defect.

A barium enema, 7–10–'45, shows a persistence of the filling defect in the sigmoid.

This case shows no change eight months after having put the area at rest. Resection should be done. It has been deferred because of a respiratory infection. The plan contemplated is to resect the lesion, and, at that time, close the left inguinal colostomy. Later, at another stage, to close the transverse colostomy.

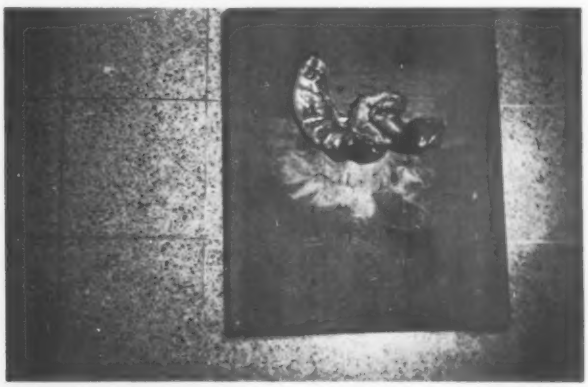

FIG 3.—Kodachrome of the gangrenous resected ileum (30 cm.)

Case 5 illustrates the inadvisability of forcing barium through an almost completely obstructing lesion, any considerable distance beyond the constricted area. In our experience, with both carcinomatous and irradiation-obstructing lesions of this degree, preliminary proximal diverting colostomy is indicated.

CONCLUSIONS

It is important to be aware of the fact that complaints of recurring, severe, cramp-like pain occurring a few months or several years later, in patients having previously had irradiation therapy for cervix and corpus uteri carcinoma, may be due to the late-effects of irradiation. These may produce incomplete or complete obstruction due to vascular change and fibrosis following edema.

Abdominal exploration after appropriate study and observation is indi-

cated. One must not assume that the picture is necessarily one of extension of the primary pathology.

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THE ANATOMY OF THE PERI-ESOPHAGEAL VAGI

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THE REVIVAL OF CLINICAL INTEREST in vagotomy as a surgical procedure for peptic ulcer stimulated this investigation of the anatomy of the esophageal vagi. Examination of the standard text books of anatomy provided insufficient anatomic description of surgical value. However, McCrea,[1] Hovelacque,[2] and Mitchell[3] have published excellent descriptions of the infra-aortic portion of the vagi and the innervation of the gastro-esophageal junction. Their studies showed that the right and left vagi and the esophageal plexus formed an extremely complex and varied arrangement of nerve structures.

Methods and Material.—A total of 32 gross dissections on cadavers were carried out after the lungs and heart were removed, and the diaphragm sectioned through the esophageal hiatus. The esophagus and its associated vagal nerve structures were carefully examined. No attempt was made to define the very fine nerve filaments entering the musculature of the esophagus nor the sympathetic fibers emanating from the sympathetic trunk, the splanchnics or the peri-aortic plexus. The dissection was started at the point of reformation of the right and left trunks from the pulmonary plexus just below the bifurcation of the trachea, and continued down through the diaphragmatic hitaus. The formation of the complex anterior and posterior gastric plexus, and the branches to the coeliac plexus, were not examined. Diagrammatic drawings were made of each dissection; the sketches, pictured in Figures 2, 3, 4 and 5 were not drawn in proportion in any way but were intended to enable surgeons to visualize as a whole the complex arrangements of the peri-esophageal plexus in its variations from one individual to another.

Findings.—As can be seen from examining the diagrams, the specimens all varied in the number of fibers forming the infra-aortic right and left vagal trunks, in the arrangement of the peri-esophageal plexus, in the way the anterior and posterior vagal trunks were formed and in the number of separate fibers that passed through the esophageal hiatus. In general, close examination revealed a basic conformity to four well-defined types (Fig. 1); those in which the right and left vagi communicated through anterior fibers (11 cases); those in which no communicating fibers could be found (1 case); those in which communicating fibers were all posterior (6 cases), and the last group in which communicating fibers were present both anteriorly and posteriorly (14 cases).

The right and left vagi after reforming from the pulmonary plexus, emerged along the lateral borders of the esophagus as a varying number of

separate fibers, usually one to four (Table I). These fibers remained lateral to the esophagus for a distance of one to two inches, often communicating or merging with each other. They then followed the course of the esophagus as it inclined to the left and became closely adherent to its musculature, arbor-

TABLE I

NUMBER OF SEPARATE FIBERS PRESENT IN VAGAL TRUNKS EMERGING FROM THE PULMONARY PLEXUS

	Number of Fibers			
	1	2	3	4
Right vagus.....	12	10	7	3
Left vagus.....	9	12	11	0

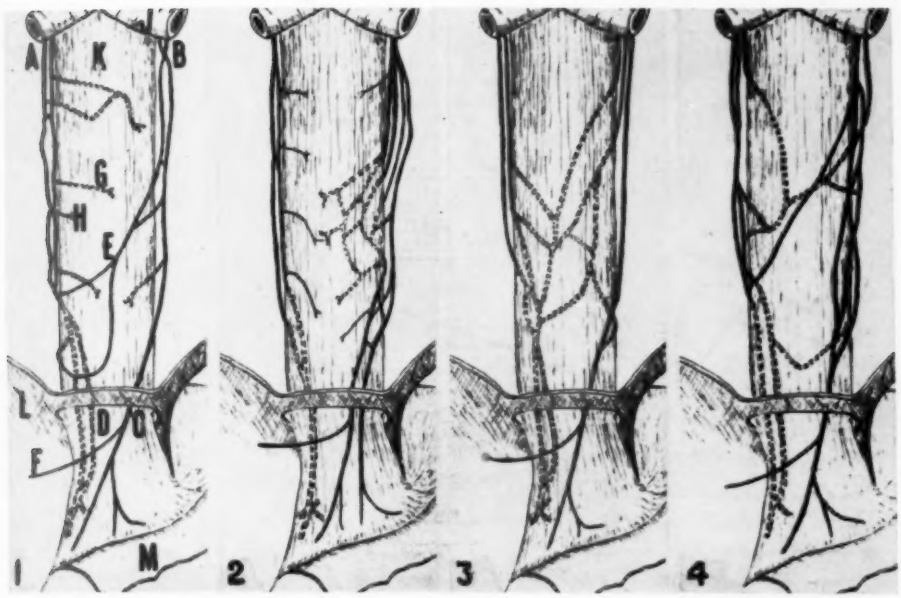

FIG. 1.—The diagrams illustrate four different types of anastomosis between the right and left vagal trunks in the formation of the peri-esophageal vagal plexus. (1) Anterior communicating branches only; (2) no communicating branches; (3) posterior communicating branches only; and (4) anterior and posterior communicating branches. (A) right vagal fibers; (B) left vagal fibers; (C) anterior vagal trunk; (D) posterior vagal trunk (2 fibers in this case); (E) anterior communicating vagal fibers; (F) Hepatic fiber; (G) posterior short esophageal fiber; (H) anterior esophageal fiber; (I) trachea; (K) esophagus; (L) portion of diaphragm showing diaphragmatic hiatus; and (M) stomach with peritoneum stripped off to expose gastro-esophageal junction. The vagal branches lying anterior to the esophagus are shown as solid line, the fibers lying posteriorly as double dotted lines. The right and left vagal trunks are shown pulled away from the lateral walls of the esophagus, to simplify the illustrations.

izing and sending out communicating fibers to each other as described above. At about the level of the distal third of the esophagus the anterior and posterior vagal trunks usually became well-defined, as a rule, the posterior as a continuation of the main fibers of the right vagus and the anterior as a continuation of the left vagal fibers. The right and left vagal trunks usually

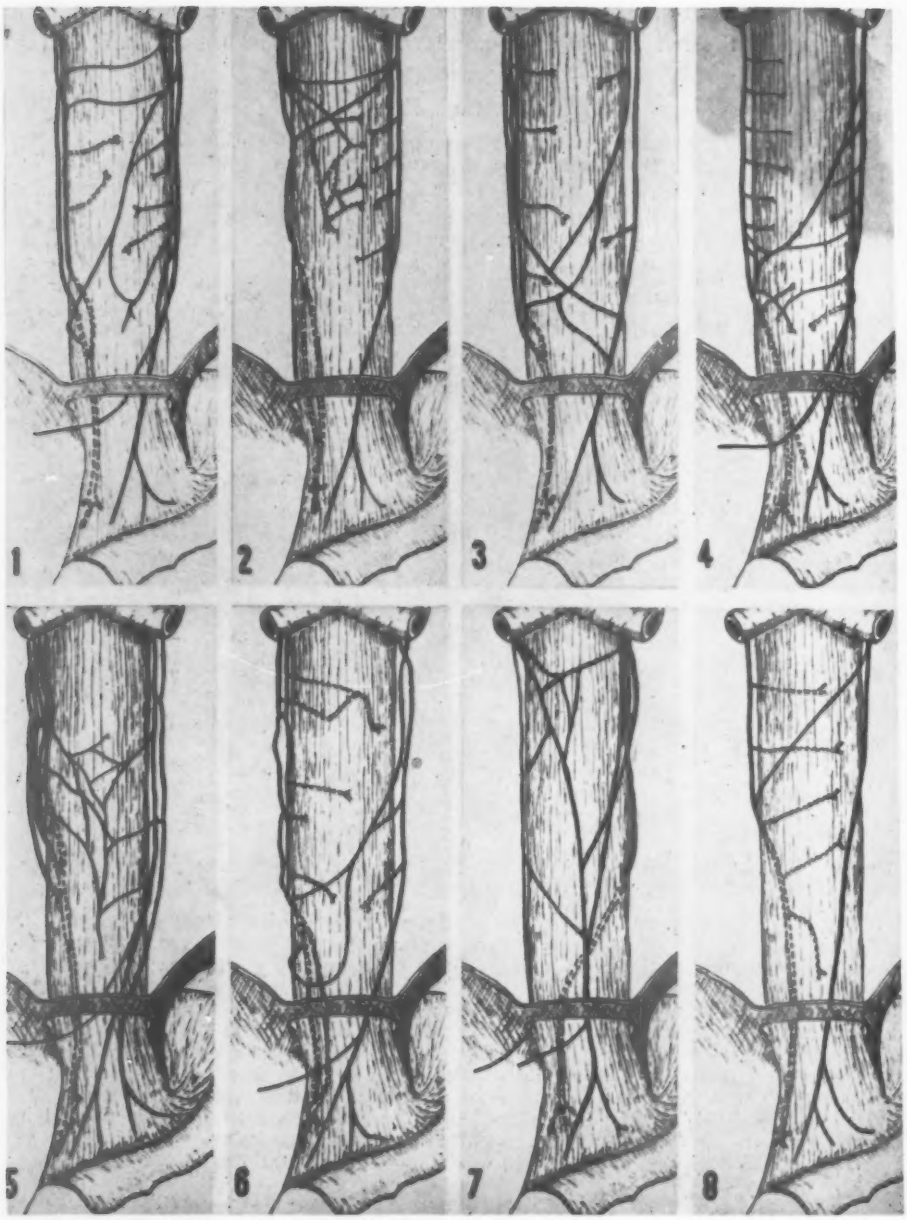

FIG. 2.—Diagrams illustrating the variation in the origin of the infra-aortic vagi; the mode of formation of the peri-esophageal plexus; and of the anterior and posterior vagal trunks, and their passage through the esophageal hiatus. In these eight specimens only anterior communicating branches were found.

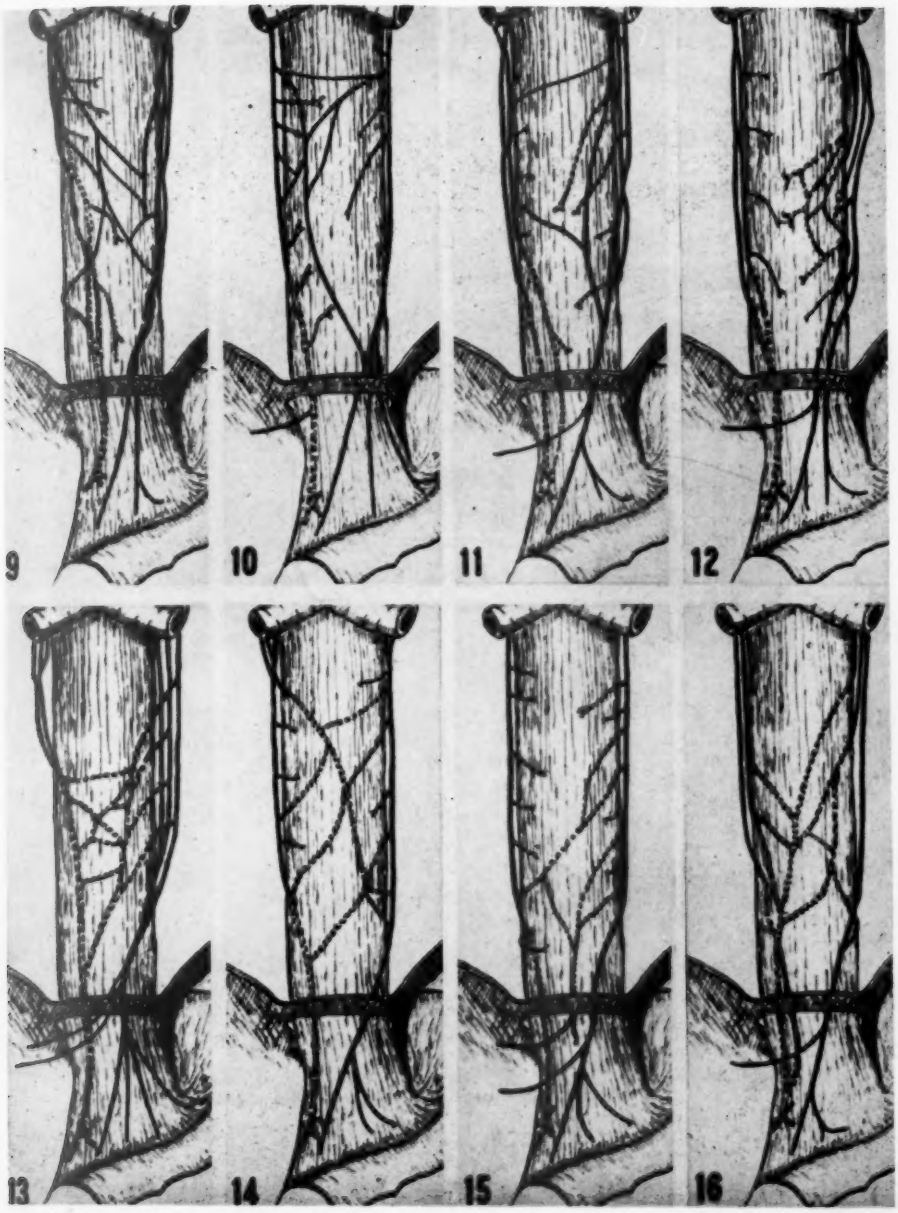

FIG. 3.—Diagrams illustrating variations in the formation of the peri-esophageal vagal plexus. Anterior communicating branches only (Nos. 9–11); no communicating branches (No. 12) and posterior communicating branches (Nos. 13–16).

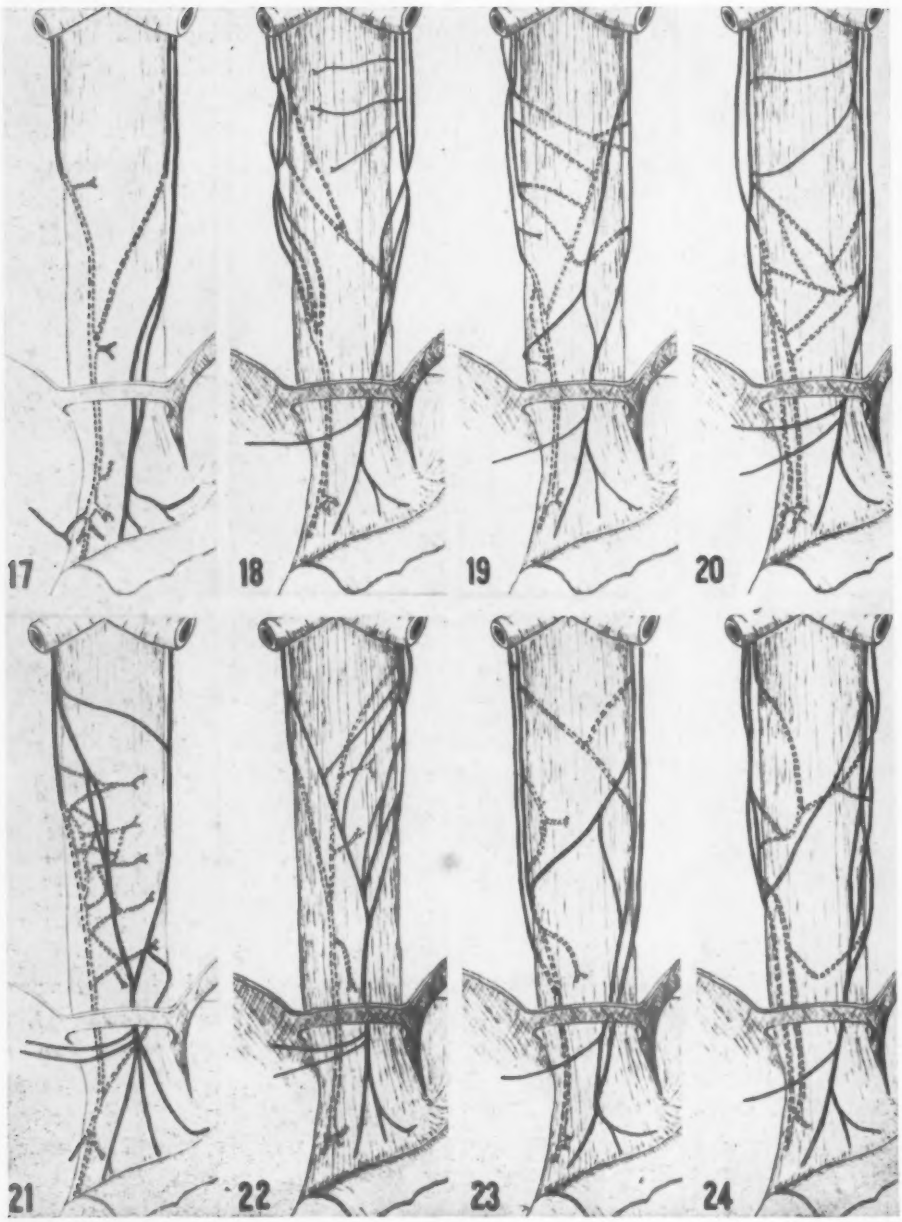

FIG. 4.—Diagrams illustrating variations in the formation of the peri-esophageal vagal plexus. Posterior communicating branches (Nos. 17 and 18), anterior and posterior communicating branches (Nos. 19–24).

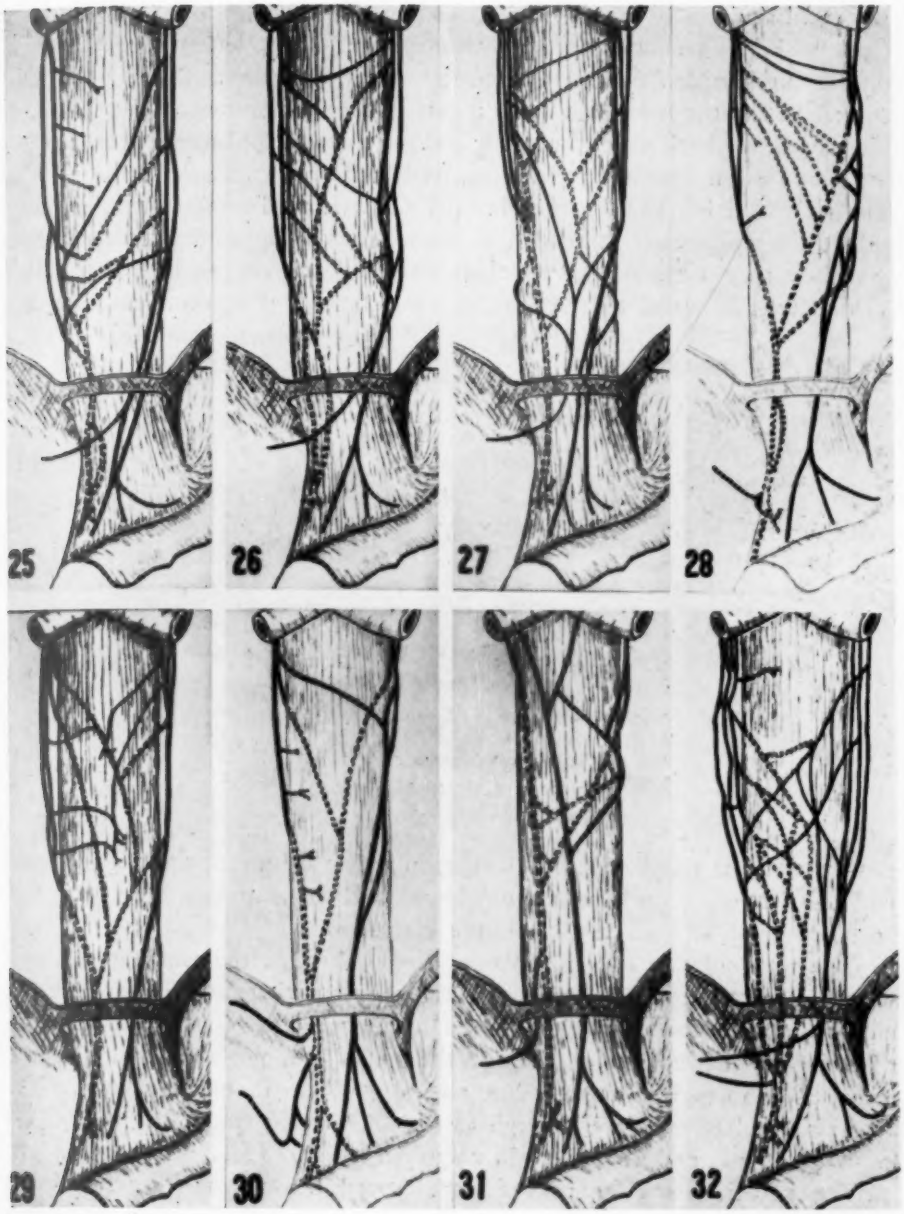

FIG. 5.—Diagrams illustrating variations in the formation of the peri-esophageal vagal plexus. Anterior and posterior communicating branches. (Nos. 25–32)

were connected with each other by communicating branches, either anterior (No. 1–11) or posterior (No. 13–18) communicators, or both (No. 19–32). Frequently the anterior communicating branch arose from the right trunk while the posterior communicator arose from the left trunk. The communicating branches not only served to connect the two vagal trunks but also contributed to the formation of an anterior or posterior esophageal plexus or plexus gulae. Both the right and left vagal trunks supplied short esophageal branches which ran transversely and entered the substance of esophagus. The right and left vagal trunks formed and reformed in their course alongside the esophagus, but tended to maintain the approximate number of branches they contained after their origin from the pulmonary plexus. Within two inches of the esophageal hiatus, the vagi lay both anterior and

TABLE II

NUMBER OF SEPARATE VAGAL FIBERS PASSING THROUGH THE ESOPHAGEAL HIATUS

	Number of Fibers			
	1	2	3	4
Total	..	9	17	6
Posterior	20	11	1	0
Anterior	20	10	2	0

TABLE III

ORIGIN OF HEPATIC FIBERS

Arising from anterior vagal trunk	19
Arising from posterior vagal trunk	3
Arising from both vagal trunks	3
Not found	7

posterior to the esophagus. However, in a few instances, the vagal trunks pursued a course parallel to the esophagus without assuming the anterior or posterior position until just inside the hiatus.

The total number of vagal fibers passing through the esophageal hiatus were not limited, as commonly conceived, to an anterior and posterior branch, but frequently came through as three or four branches (Table II). The posterior vagal trunk passed through the hiatus as a single fiber in 20 specimens, as 2 fibers in 11 specimens, and as 3 fibers in one specimen. The anterior vagal trunk came through as one fiber in 20 specimens, as 2 fibers in 10 specimens, and as 3 fibers in 2 specimens.

The hepatic nerve or nerves were traced through the layers of the lesser omentum to the liver. In 19 dissections, the hepatic nerve or nerves arose from the anterior vagal trunk, in three cases from the posterior trunk, and in three cases from both the anterior and posterior vagal trunks. In seven cases, the hepatic nerves were not defined (Table III). In six specimens the hepatic nerve (Nos. 1, 4, 5, 13, 26 and 27) arose from the anterior vagal trunk above the esophageal hiatus and passed through the foramen as

a separate fiber. Similarly, in two cases (Nos. 7 and 31) the hepatic nerve arose from the posterior vagal trunk above the hiatus. In one case, (No. 7) the hepatic nerve was traced as a direct branch of the right vagal trunk. In this case the posterior vagal trunk appeared to be derived directly from the left vagus. In another dissection (No. 27) the hepatic nerve was a direct continuation of the communicator nerve. In a number of cases (Nos. 5, 8, 9, 22 and 23) the interesting observation was made of esophageal branches which were traceable intrinsically through the esophageal muscle fibers for considerable distance down towards the esophageal hiatus. None of these could be followed definitely through the hiatus.

From the above description of the peri-esophageal vagi it is apparent that vagotomy can be accomplished by an approach through the left chest exposing the infra-aortic esophagus.[4] Thorough vagal section can be obtained either by careful search, not only for the vagal trunks, but also for the main connector branches. By means of peri-esophageal stripping, surgical denervation can thus be accomplished. Similarly, if an approach through the upper abdomen is considered necessary, vagotomy can be also effected by mobilizing the lower part of the esophagus and clearly exposing the boundaries of the hiatus to reveal all the vagal branches passing through it.

SUMMARY

The mode of origin, peri-esophageal ramifications, and course through the esophageal hiatus of the infra-aortic vagi in 32 cadaver specimens, are described and illustrated by separate diagrams.

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PROLONGED INTERCOSTAL NERVE BLOCK IN UPPER ABDOMINAL OPERATIONS

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IN A PREVIOUS REPORT[1] the use of intercostal nerve block with a long-acting anesthetic agent in connection with upper abdominal operations was described. The results obtained in this small series of 20 cases were favorable, and it was decided to continue its use to secure further information and make a better evaluation of its usefulness and possible rôle in postoperative care.

The original thought was that two possible advantages might be obtained, the elimination or reduction of postoperative pain and discomfort and a lower incidence of postoperative pulmonary complications. These are interrelated. The pulmonary complications usually start with an area of atelectasis at which a pneumonic process later supersedes. This primary atelectasis is due to greatly reduced respiratory excursions produced by a combination of factors all dependent upon pain from the abdominal incision and attempts by the patient and doctor to alleviate them. These factors are splinting of the diaphragm, tight abdominal dressings and binders, reluctance to take deep breaths, and to cough up gathering mucous plugs, to morphine and other analgesics, and the tendency of the patient to remain in one position.

The problem is not a new one, and several efforts in the past to find the proper solution made progress in the right direction. Gius[2] found that in two cases which developed postoperative atelectasis, paravertebral block with procaine of the nerves supplying the operative area (in these instances lower thoracic and upper lumbar following appendicectomy) eliminated the pain from the wound, allowing deep breathing, easy coughing, and freedom of movement. The offending plugs of mucus and bronchial secretions were dislodged and expectorated with rapid reëxpansion of the involved lung areas.

An attempt was made by Crile[3] to produce a local anesthesia of the wound by injecting one-sixth to one-half per cent solution of quinine and urea hydrochloride. The anesthesia obtained was satisfactory, lasting for several days, but the method was discarded because it produced a fibrinous exudate with occasional suppuration at the sites of injection.

Another effort along this same principle was made by Capelle,[4] who tried the continuous administration of a procaine solution into the wound area. He used several large, thin, curved, hollow needles which were placed like retention sutures and served as outlets to irrigate the wound with the anesthetic solution when required. This method has been discarded for technical reasons.

A few years ago Bartlett[5] wrote the classical description of the blocking of the lower intercostal nerves to produce upper abdominal anesthesia. He

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pointed out that in the midaxillary line they were easily accessible and could be reached with great accuracy. Bartlett described the use of the block of the 6th to the 11th intercostal nerves as producing anesthesia of the upper abdominal wall with relaxation of the musculature, and showed how it could be used to advantage, when combined with light general anesthesia in operations upon the upper abdomen.

Using this technic, and adapting it to this particular problem of postoperative atelectasis, Starr and Gilman,[6] in a series of cases, performed intercostal blocks about 24 hours postoperatively, and showed that there was a marked increase in pulmonary ventilation. The relief of pain allowed the patients to move about more readily, coughing was much easier with ability to raise sputum enhanced, and there was an increase in vital capacity.

The next step was reported by Zollinger[7] who, in a series of 15 cases, performed intercostal blocks with a solution of eucupin in oil to obtain anesthesia of several days' duration. From 1.5 to 5 cc. were injected in each space. Measurements of vital capacity showed an increase over the readings obtained in a control group who did not have the block. The resulting anesthesia using both unilateral and bilateral blocks was not uniformly good, but he stated the method warranted further trial.

METHOD

The technic used for performing the intercostal block was that described by Bartlett and adapted for use in this respect as already reported. Briefly, it is as follows: After the anesthesia for the operation had been started, the arm was raised above the head, thus, exposing the midaxillary line for injection. The area was sterilized and sterile technic was used throughout the procedure. One and one-half to two cubic centimeters of solution were deposited just under the inside and lower border of ribs 6 through 11. In the first few cases the injections were made before the anesthetic for the operation was started. This proved unsatisfactory since the pain incidental to the procedure was distressing to the patient. In all successive cases the block was done after the induction of anesthesia. When spinal anesthesia was being used, the intercostal block was done after the level of anesthesia had risen to the fourth or fifth thoracic segment. With a general anesthetic, it was done after induction while an assistant maintained the anesthesia. In this way the patient was spared the ordeal of multiple injections.

At first all cases received a bilateral block, but it was soon realized that if the incision were placed one inch or more from the midline a unilateral block would be sufficient.

TABLE I

Bilateral	42
Right	39
Left	19

The number of each done is shown in Table I. The tendency was to do only the right side for operations on the biliary system, and the left for gastric

surgery. Ventral and epigastric herniae received bilateral blocks as did those cases with midline or transverse incisions.

There was no attempt at selection of cases. Every upper abdominal operation, in which the anesthetic was administered personally, also received an intercostal block. There was no effort to choose those cases which might appear more favorable. The reverse might be more likely, since it was the poorer risks which received personal attention, a staff of nurse anesthetists being available for the uncomplicated cases. It was thought best to take every case that came along in an endeavor to obtain a true picture of the efficacy of the procedure.

A variety of anesthetic agents was used in these cases, as is illustrated in Table II.

TABLE II

Spinal	24
Continuous spinal	17
Local	1
Sodium pentothal	3
Spinal and cyclopropane	1
Nitrous oxide–oxygen–ether	3
Cyclopropane-oxygen	7
Cyclopropane-oxygen-ether	44

As a rule the gastric resections were done under continuous spinal anesthesia, the others being fairly evenly distributed. If no special indication or contraindication existed to influence the choice of anesthetic, the selection was left to the surgeon or patient, depending upon who had a marked preference for any method.

The operative procedures performed are listed in Table III. Practically every upper abdominal procedure is included in this group of cases.

TABLE III

Cholecystectomy	37
Cholecystectomy and appendiectomy	14
Common duct exploration	4
Cholecystostomy	2
Cholecystectomy and hepatoduodenostomy	1
Gastric resection	9
Gastro-enterostomy	17
Gastrostomy	5
Gastrorrhaphy	3
Closure of gastric fistula	1
Exploratory for inoperable carcinoma	4
Epigastric hernia	3

The time of operation varied, some of the procedures taking less than one hour, others up to four hours. Most of the cases took between 1.5 and 2 hours. The sex distribution was fairly even—54 males and 46 females.

Most of the patients fell into the older age-group, as seen in Table IV. This was to be expected since these lesions most commonly occur in such age-groups. Eighty per cent of the patients were over 40 years of age, and 50 per cent were over 50 years of age.

TABLE IV

20–29	5
30–39	15
40–49	30
50–59	29
60–69	14
70 and over	7

The agent used in this series of cases was Novest-Oil, which is a solution of monocaine base in oil of sweet almonds with the following formula:

Monocaine base	0.02 Gm.
Benzyl alcohol	0.05 Gm.
Benzocaine	0.03 Gm.
Oil of sweet almond	to 1.0 cc.

This anesthetic in oil is one of those commonly used for the relief of pain following rectal operations, and since it appeared to have no deleterious effects when injected around the rectum it was selected for use in this procedure.

The patients in this group were not informed of the reason for the intercostal block and many of them did not even know that it had been done. No mention was made of the fact that they might expect relief from or abatement of their postoperative pain. The usual orders for postoperative sedation with an opiate, either morphine sulphate or pantopon were left, to be given if the patient complained of pain. No attempt was made to withhold needed sedation from the patient.

RESULTS

It was decided to judge the efficacy of the block by the amount of sedation required to eliminate any pain the patient might have during the postoperative period. Table V shows the tabulation of the number of doses of opiate required by the patients.

TABLE V

None	42
1	26
2	11
3	5
4 or more	16

The block was considered successful if three or less injections were administered during the postoperative period, and unsuccessful if four or more were administered. This has been an arbitrary division but is based on clinical observation. Often one dose was given while the patient was reacting from the general anesthetic to control his restlessness and excitement. In some instances opiates were given at bedtime for sleep, the nurses taking advantage of the fact that an order had been left to give the patient a good night's sleep.

Therefore, on the basis of these figures, the intercostal block produced the desired analgesia in 84 cases and failed in 16 cases. Some of these failures

might be due to psychic reasons, since patients who knew they were submitted to major surgery expected pain and called for sedation at the slightest discomfort. Most, however, were probably due to inaccuracy in the technic, the anesthetic solution not being deposited in close enough proximity to the nerve trunk. Technical difficulty was encountered in some patients of marked obesity where three-inch needles had to be used to reach the ribs. Some patients who became markedly distended required sedation for their distention rather than for pain at the operative site.

There were seven deaths in this series as follows:

(1) Acute left ventricular failure on the 3rd postoperative day.
(2) Peritonitis and uremia.
(3) Intestinal obstruction followed by atelectasis, pneumonia, evisceration, wound infection and pulmonary embolus.
(4) Coronary occlusion on the 15th day.
(5) Pulmonary embolus on the 15th day.
(6) Pulmonary embolus on the 10th day.
(7) Carcinomatosis.

None of these can in any way be attributed to the intercostal block.

There were three cases of atelectasis in the 1st postoperative days, which cleared spontaneously when the patient was encouraged to cough and pounded on the back. Tracheal suction was attempted but the catheter rarely entered the trachea, the desired result being obtained when the patient coughed from stimulation of the pharynx by the catheter. In all these cases the block was successful when judged by the criterion of absence of postoperative pains, none of them requiring sedation. However, it was difficult to obtain the coöperation of these patients to cough, due perhaps to a combination of sluggish mentality and language difficulty. However, persistent personal attention on the part of the surgical house staff impressed them with the importance of coughing and expectorating plugs of mucus.

There was one case of bronchopneumonia in an extremely uncoöperative patient who had no pain relief, requiring sedation every four hours for three days. In one patient who had a successful block but became severely distended a pneumonia developed on the 7th postoperative day.

There were four instances of right pleural effusion, all in cases which had successful results from the block. These absorbed spontaneously, although one required thoracentesis on two separate occasions.

Discussion.—Since the relief of postoperative pain is the desired result and the detrimental features of the postoperative course which are to be eliminated all stem from this, it was decided to accept pain relief as the criterion for a successful block. It was found that on this basis good results were achieved in 84 per cent of the cases. There are several reasons for the failure in 16 per cent. Although the block itself is easy to perform, there are six nerves to be injected, and failure to anesthetize any one of them renders the whole procedure worthless. Many of these patients, especially the gall-

bladder group, are inclined to obesity, making the block technically difficult. In several cases, needles used ordinarily for lumbar puncture were substituted here to reach the desired depth. Another technical factor was the small quantity of fluid deposited at each space. Never more than 2 cc. was used in one place, since there is some danger of abscess formation from the pooling of an oily solution in one place in the tissues. Intercostal block when done with an aqueous solution as procaine for anesthesia rarely fails, for here 5 cc. are used at each interspace. In a few of the cases the incision was probably made too near the midline and overlapping innervation from the other side negated the analgesia in unilateral blocks.

As is more or less inevitable following surgical procedures and anesthesia, some of these patients developed varying degrees of abdominal distention and required sedation for relief of the accompanying pain. Although in these instances the opiates were not given for pain arising from the incision and operative procedure, still it is counted as postoperative sedation in the final tabulation.

There are several interesting features about the three cases which developed postoperative atelectasis. They were all women who had had cholecystectomies performed under cyclopropane-oxygen-ether anesthesia, were all from the same ward, and were all operated upon within a space of three weeks by different surgeons. The anesthetic used and the fact that there were none under spinal anesthesia might lead one to conclude that inhalation anesthesia might be a predisposing factor. This has been shown to be not true in large series of controlled cases. More likely, is the fact that all these cases were from the same ward and in a short space of time and, hence, were due to a lack of attention from the nursing staff in regard to emphasizing to the patient the importance of coughing up gathering plugs of mucus. When there is a training school and a rapid turnover of student nurses on a floor a situation like this may occasionally develop, especially with a shortage of experienced personnel as occurred during the war years. This finding again lays stress upon the fact that attention to the frequent changing of position and encouragement to cough are essential to the prevention of postoperative pulmonary complications.

The four cases which developed pleural effusions deserve further consideration. All were females upon whom cholecystectomy had been performed, three under spinal and one under general anesthesia, by two different surgeons. In all instances there was only a unilateral intercostal block done on the right side which was successful for relief of postoperative pain, and in all instances the pleural effusion occurred on this same right side. In three of the patients the fluid was absorbed without any interference, but in the fourth, thoracentesis was done on two occasions to remove a total of 1,100 cc. of fluid, which was clear and from which no organisms could be cultured.

The etiology of this sterile fluid seems to be some irritant stimulating the pleura. Probably when the block was being done some of the fluid was inadvertently injected into the pleural space with the resultant effusion. The proximity of the pleura to the intercostal nerve is thus stressed and great care

must be taken at each injection to make sure that all is deposited in the tissues and none in the pleural space. It had been hoped that the agent used would not stimulate the pleura or be an irritant, but apparently in some cases it did. Most likely it was the oily solvent that proved to be the irritating factor.

The incidence of postoperative pulmonary complications in the group of cases in which the block was successful in relieving pain was very low. The three cases of atelectasis responded nicely to conservative "stir-up" therapy, and the one case of pneumonia developed on the 7th postoperative day following a severe abdominal distention at a time when the block could no longer be of use. This is undoubtedly much better than would have been obtained in a similar group of patients and operative procedures had they not received the intercostal block.

The clinical picture presented by these people in their postoperative period was very gratifying. They were free from pain or suffered only slight discomfort in most instances. When requested, they were able to take deep breaths or cough without any pain. They moved about in bed freely and were comfortable. The difference from the average patient who has gone through a similar procedure was remarkable.

In several of the cases an opportunity presented to study the patient on two different occasions after the same type of upper abdominal procedure, once with the block and the other time without it. The patients were never told that anything special was being done to alleviate their postoperative pain.

W. H. had a gastric resection done under continuous spinal anesthesia for an ulcer. He had no pain in the postoperative period and required no sedation. The intercostal block had worked perfectly. On the 14th postoperative day he suddenly exhibited the typical picture of peritonitis and was explored. No pathology was found and he was closed and returned to the ward. No block was done on this second operation, and the patient required morphine at four-hour intervals for 48 hours. On the 10th day following his second operation, as he was about to get out of bed, he died suddenly. Postmortem examination showed a large pulmonary embolus as the cause of death. Sections of several of the intercostal nerves were removed and examined histologically at this time (24 days following injection) and no trace of the oily anesthetic agent was found, nor were there any signs of damage to the nerves or their fibers.

H. H. had a gastric resection performed for a penetrating duodenal ulcer under continuous spinal anesthesia. He required morphine every four hours for the first three postoperative days. About six weeks following this operation a celiotomy was performed for closure of a gastric fistula. This time intercostal block was done, and the patient required no sedation postoperatively.

These two cases illustrate the response of the same patient to successive operative procedures both with and without an intercostal block and demonstrate its efficacy for the relief of pain.

In a third patient, S. H., two operations were performed, repair of a ventral hernia and removal of a common duct stone, both under spinal anesthesia.

intercostal block being done in both instances and with good results. This illustrates the fact that the same nerves can be injected twice with good results both times.

In none of the cases was there found any residual signs from the intercostal block. There were no permanent effects upon the nerves and no paresthesias or hypesthesias.

CONCLUSIONS

The blocking of intercostal nerves 6 through 11 with an anesthetic in oil will, in the majority of instances, give relief of postoperative pain.

The usual postoperative pulmonary complications expected following these procedures have been greatly reduced in number.

There exists a danger of pleural effusion if the oil is inadvertently injected into the pleural space.

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A TECHNIC FOR BLOCKING THE CAROTID SINUS NERVES

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IN ESTABLISHING the clinical diagnosis of an hyperactive carotid sinus reflex, the syndrome must be reproduced by digital compression of the carotid sinus region. In order to ascertain that the hypersensitivity of the carotid sinus is really causing the condition, the compression maneuver should fail to bring on this reaction after blocking the carotid sinus nerves by an analgesic solution. An accurate technic of blocking the carotid sinus nerves, therefore, renders indispensable assistance in confirming the diagnosis as well as in casting the prognosis, particularly, when surgical intervention for relief is planned. In searching through the pertinent literature dealing with the therapy of the hyperactive carotid sinus reflex, several authors (Weiss,[8] in 1936, and White and Smithwick,[9] in 1941) recommend diagnostic block of the carotid sinus nerves. No specific description of the technical procedure has appeared previously, perhaps with exception of a brief account given by Rovenstine and Cullen[5] (1939). The technic presented here is based upon anatomic and radiologic studies, as well as on the clinical application in approximately 50 patients.

THE CAROTID SINUS REFLEX

To maintain the normal level of the blood pressure, the vascular tree is endowed at various places with nerve endings responding to distention. When stimulated, particularly by increased blood pressure, a message is sent through afferent nerves to the vasomotor area in the brain which relays this stimulation to efferent cardiac decelerators as well as to vasodilators. This restores the normal level of the blood pressure. The *carotid sinus reflex* is one of the important blood pressure moderators. Its implication was fully appreciated by Hering[3] (1927), and Heymans[4] (1933). The *stretch* receptors are located in the adventitia of the carotid sinus, *i.e.*, a dilatation of the common carotid artery at its bifurcation. The majority of the receptors are located within the wall of the root of the internal carotid artery (De Castro,[2] 1928), although they may also extend to the common and external carotid arteries. The *afferent limb* of the reflex arc is in the main the carotid sinus nerve, a branch of the glossopharyngeal, and to a lesser extent the vagus. After leaving the petrosal and nodose ganglia the impulse enters the brain at the medulla, whereupon it is relayed to the vasomotor area. *Efferent vagal fibers* effect slowing of the *cardiac activity*. Peripheral vasodilatation is mediated through sympathetic pathways. Although the vasodilatory

mechanism has not been accurately analyzed, it is assumed that this phenomenon is induced by the inhibition of vasoconstrictors and the activation of vasodilator nerves (Heymans, Bouckaert and Regniers,[4] 1933).

THE ANATOMY OF THE RECEPTOR NERVES

The interruption of the reflex arc is conveniently performed by blocking its *afferent limb, i.e.,* shortly after its departure from the carotid sinus. As shown recently by Sheehan, Mulholland and Shafiroff[7] (1941), the origin of these nerves is not simple, for they are interlaced as to form an intricate network which has been designated as the carotid sinus nerve complex. The latter inosculates in a variable fashion with the glossopharyngeal, vagus, sympathetic and occasionally the hypoglossal nerves. The complex is located between and somewhat behind the fork of the carotid bifurcation.

TOPOGRAPHY OF THE CAROTID BIFURCATION

Since this location represents an important deep landmark for blocking the carotid sinus nerve complex, a brief account of its relations and variations shall be given here. The carotid bifurcation, situated within the carotid fossa of the anterior triangle of the neck, is encased in the fascial sheath which encloses the common carotid artery, including its branches, the internal jugular vein and the vagus nerve. This sheath rests upon the prevertebral muscles which harbor in their fascia the cervical sympathetic trunk. The superior laryngeal nerve is often included in the block, because it travels in close proximity to the posterior aspect of the carotids on its way to larynx. The *carotid sinus nerves* course within the carotid sheath in front of the prevertebral muscles towards the gates of the basis of the skull. The relation of the carotid bifurcation to the skeleton is variable. In the upright anatomic posture it is located at the upper border of the thyroid cartilage. Because this relationship changes, particularly with the neck in extension, it is of but little use as a landmark in the blocking procedure. For practical purposes, more attention is paid to the relation of the carotid sinus to specific points of the spine. Commonly, the carotid bifurcation is placed in front of the anterior tubercle of the transverse process of the 4th cervical vertebra. According to Schwalbe[6] (1878), and Binswanger[1] (1879), however, this position varies frequently. It may be found in front of the transverse process, anywhere from the 3rd down to the 5th cervical vertebra and, it is as a rule, somewhat lower on the left side. In individuals with a short neck the bifurcation is located at a higher level than in those with long necks.

TECHNIC OF NERVE BLOCK

Superficial and deep landmarks of the mandible and cervical vertebra are used as guides for directing the needle into the intercarotid space. The latter is located just above and behind the pulsating carotid sinus. The deposition of procaine solution into this area will block the carotid sinus nerve complex.

PREPARATION OF THE PATIENT

Prior to the actual insertion of the needle the following dictums should be observed: (1) No preoperative medication should be given, for this will interfere with the test. (2) In order to ascertain the existence of an irritable carotid sinus reflex, digital compression on the carotid bifurcation should precipitate a specific symptom-complex. Positive reactions are noted by recording the changes of the blood pressure, quality and rate of the pulse of the radial artery, variations of the respiration and state of consciousness. (3) The patient lies in the supine position on the examining table, with a soft

FIG. 1.—Skin markings to determine the site of introducing the needle. Line I corresponding to the triturating line of the teeth. Line II, perpendicular to Line I, runs through the projection of condyle of the mandible C. M.
(A) is the point of crossing of Lines I and II.
(B) corresponds to the anterior tubercle of the 6th cervical vertebra.
(I) marks the site of introducing the needle 1 cm. in iront of the midpoint between A and B.

pillow under the shoulders and a sandbag or aircushion under the external occipital protuberance. These are arranged so that the head and neck are slightly extended in the midline position. (4) *Plotting the site of injection:* The point of introducing the needle is located on the lateral aspect of the neck at the height of the *anterior tubercle* of the 4th *cervical vertebra.* This level is determined by drawing the following lines on the face and neck with a skin pencil (Fig. 1). Line I extends posteriorly, from the angle of the mouth across the face on to the neck. It corresponds to the triturating surfaces of the teeth (Fig. 2A). Line II descends from the level of the posterior border of the mandibular condyle, forming a right angle with Line I at point A (Fig. 1). Line II, when properly placed, lies in the projection of

the posterior tubercles of the transverse processes of the 2nd, 3rd, 4th and 5th cervical vertebrae; because of the lordosis of the cervical spine Line II arrives at the anterior tubercle of the 6th cervical vertebra, *i.e.*, point B (Fig. 2A). The posterior tubercle of the 4th cervical vertebra is located midway between points A and B. Point A is the point of crossing of Line I and Line II; and B corresponds to the anterior tubercle of the 6th cervical vertebra (Fig. 1). The skin projection of the anterior tubercle of the 4th cervical vertebra lies one centimeter anterior to the midpoint of A–B. This

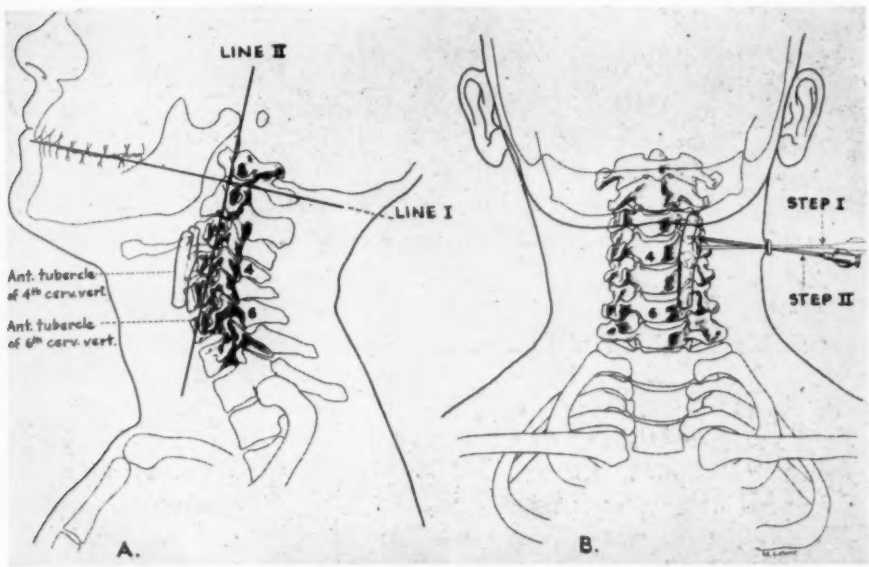

FIG. 2.—Tracings from radiographs of the bony landmarks of the neck.
(A) shows Line I coursing along the triturating line of the teeth and the 2nd cervical vertebra. Line II, perpendicular to Line I, passing along the posterior border of the condyle of the mandible and the transverse processes of the vertebrae. The carotid sinus is located in front of the anterior tubercle of the 4th cervical vertebra (marked with a block dot).
(B) *Step I:* The tip of the needle located on the anterior tubercle of the 4th cervical vertebra.
Step II: The final position of the needle. Its tip is located slightly above and behind the carotid bifurcation.

marks the site of introduction of the needle (Figs. 1 and 2A). After the superficial landmarks have been accurately determined, the area is prepared with the usual surgical antiseptic precautions. The head is then turned slightly to the opposite side without altering the position of the spine from the midline. An intradermal analgesic wheal is raised at the site of introduction of the needle.

Step I. A 50-mm. by 0.7-mm. Labat-type needle, threaded with a rubber depth recorder which is placed 3cm. from the tip, is inserted directly perpendicular to the sagittal plane of the neck. The needle should contact the anterior tubercle of the 4th cervical vertebra no further than the depth of the recorder (Fig. 2B). For the purpose of identification the operator should

be able to pass in front of the tubercle without meeting bone. To accomplish this, the rubber recorder is retracted an additional centimeter from the tip of the needle, its shaft is withdrawn for approximately 2 cm., the hub is moved slightly posteriorly and the needle is reinserted. After establishing the identity of the anterior tubercle of the 4th cervical vertebra, the needle, with the rubber recorder again set 3 cm. from the tip, is reinserted to this point as originally described.

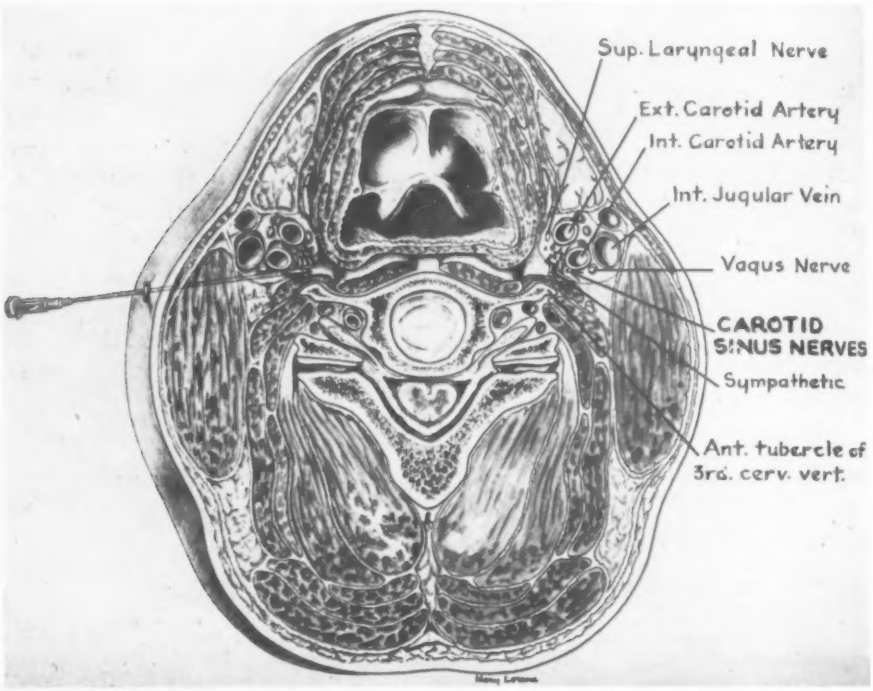

FIG. 3.—Cross-section through the neck at the level of the 3rd cervical vertebra, showing the relations of the structures of the neck to the penetrating needle. Its tip is located at the carotid sinus nerves slightly above and behind the carotid bifurcation.

Step II. To reach the carotid sinus nerves, the rubber recorder is again withdrawn for 1 cm. The needle is then retracted until its tip lies freely in the superficial structures and the hub is moved ten degrees posteriorly and caudally. Assuming this final position, the needle is inserted to the full depth marked by the rubber recorder. The tip will then have reached the carotid sinus nerves posterior to, and slightly above, the carotid bifurcation (Fig. 2B). On its route the needle penetrates the sternocleidomastoid muscle and after passing the posterior aspect of the internal jugular vein it enters the carotid sheath. The transmitted pulsation of the carotid artery will then be noted at the hub of the needle (Fig. 3). In individuals with a short neck, where a higher position of the carotid bifurcation is to be expected, the hub of the needle should be depressed for 15 or 20 degrees caudally

before the insertion, so that the tip may reach a higher level. When the needle has attained its proper position, the aspiration test is performed, so as to avoid an injection into the circulation. Five cubic centimeters of a 2 per cent solution of procaine is injected slowly. Before applying the second compression test at least ten minutes should elapse to attain a complete nerve block.

COMPLICATIONS

(1) Hypersensitivity to procaine solution, although rare, is noted by the local reaction of the skin to the raising of the intradermal wheal. If present, the test must be discontinued. (2) Injecting into the blood stream or subarchnoidal space can be avoided by the judicious use of the aspiration test. (3) The occurrence of local hematomata can be minimized by using sharp needles. (4) Perforating the pharynx and subsequent development of infection can be avoided by strict adherence to the principles as herein described. (5) A concomitant Horner's syndrome and hoarseness due to the involvement of the cervical sympathetic and vagus nerves are of a transient nature.

Except for the occurrence of an Horner's syndrome and hoarseness in approximately 15 per cent of our series of 50 patients, none of the above mention complications have been observed.

SUMMARY

A technic of blocking the carotid sinus nerves necessary for the diagnosis and prognosis of an hyperactive carotid sinus reflex has been described. This technic is based on anatomic, radiologic and clinical studies.

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PANCREATIC CALCULI

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Though the incidence of pancreatic calculi is still generally considered to be quite low, the reports of the last 15–20 years indicate that this condition is much more common than is generally appreciated. The ease with which the condition can be recognized and the possibilities for relief by present-day surgical measures make it quite worth while to bear this disease in mind in the differential diagnosis of abdominal complaints.

Most reports on the incidence of pancreatic calculi as found by reviewing a series of autopsies indicate the finding of 1 in 1,500 to 3,000 cases.[7] In reviewing a series of abdominal films the incidence was found to be 1 in 754 cases.[7] The most significant study, however, was made by removing the pancreas in 542 cases at autopsy. The gland was then subjected to roentgenologic examination. In those which showed calcification by this method dissection was carried out. In this way 28 cases were discovered—an incidence of 1 in 20.[47]

The progress in recognition of this disease can be traced through three phases. The earliest cases were discovered quite by chance at autopsy. Such cases were of necessity rather infrequent since there may be little grossly to focus attention on this organ at postmortem examination. As abdominal surgery was more widely undertaken, with the advent of anesthesia and later of asepsis, many cases of pancreatic calculi were discovered at operation. The real progress in the recognition of this disease, however, came with the use of the roentgen-ray to demonstrate the calcifications prior to operation. The earliest case to be reported was one discovered by deGraaf,[5] in the 1660's, at postmortem examination. There were scattered reports of this sort until the turn of the 20th century. At that time abdominal surgery had opened the door for the discovery of further cases at the time of operation. In 1904, Mayo Robson[18] first hypothecated the possible value of the roentgen-ray as a means for diagnosis of this disease. It was not until 1912, however, that the first case was recognized in this manner.[44] Few more were so recognized before 1925. Since then many cases have been reported—usually following roentgenologic examination of the abdomen. Prior to 1925 only 102 cases had been reported, but during the next 13 years, as interest was focused on this disease, 102 more cases were reported.[20] Now, there are well over 200 cases in the literature.

The etiology of this disease is not clear. While many have called attention to the biliary tract disease which is associated in some cases[32] most patients show no such associated involvement. The possibility that the pancreatic disease may be secondary to biliary tract involvement seems unlikely, therefore. The consideration of reflux of bile into the pancreatic ductal system as a causative factor also is not widely credited. The calculi are made up almost

entirely of calcium carbonate and calcium phosphate; there are occasionally minor additions of organic matter. These salts are not normal constituents of pancreatic juice. We must consider, therefore, that the primary factor in the development of pancreatic calculi is that of an alteration in the composition of the external secretion of the gland. This may result from infection from any source—blood, lymphatic or ductal. A secondary factor of stasis also probably plays a rôle, but simple ligation of the duct in an experimental animal does not uniformly produce calculi. Attacks of pancreatitis may give rise to areas of calcification in the pancreas but are not the source of most calculi. Pancreatic calculi are totally different from biliary calculi. Instead, they resemble very closely those seen in the salivary glands and ducts. They are whitish or grayish-white in color and are very hard, rough and horny in contour. They are rarely faceted even though multiple. They may vary in size from that of a grain of sand up to 2.5 inches in diameter, and may weigh as much as 200 Gm.[31] Though solitary calculi have been found, usually there are multiple stones, up to several hundred in number. Their most common location is in the head of the pancreas, with decreasing frequency toward the tail, though in cases with multiple stones the entire gland may be studded with calculi. Some observers have distinguished two types of pancreatic lithiasis—a diffuse calcification within the gland and calcifications limited to the larger ducts only. Many of the former actually represent cases with hundreds of calculi, most of which will of necessity occupy the smallest ducts and, therefore, appear at first glance to lie within the substance of the gland itself.

Though certain small series have given conflicting reports as to sex-incidence, it is now well-established that the disease predominates in the male in the ratio of 3 or 4 to 1. The disease has been reported at the ages of 14 to 72 years, but occurs most commonly in the 4th and 5th decades.[53]

An occasional case is asymptomatic and is discovered quite by chance. The most common symptom, however, is that of pain. This pain typically is a severe epigastric colic resembling that seen in obstruction of the cystic duct of the gallbladder. The pain is usually located more in the midline, however, and often radiates to the left upper quadrant and back and occasionally also to the left scapula and shoulder. The colic is often severe enough to require opiates for relief, although at times the pain is of a duller and more constant nature. As in biliary colic, nausea and vomiting are frequent accompaniments of pancreatic colic. Weight loss is very common and some show frank emaciation and cachexia. Many are alcoholics. This may represent an attempt to obtain release from the pain rather than a precipitating factor in the development of the calcifications. Many also present evidence of tuberculosis; this may, however, be secondary to the extensive weight loss. As a result of obstruction to the pancreatic duct by the calculi which precipitate the attack, pancreatic enzymes cannot reach the intestinal tract. This interference may lead to changes in the stools characterized by frequent, pale, frothy, bulky stools containing increased amounts of fat. Also, there is an increase in the amounts of undigested meat fibers in the stools. Many have reported making the diag-

nosis of pancreatic lithiasis by observing the passage of calculi in the stools following an attack of colic.[26] The calculi often become impacted in the region of the ampulla of Vater. This may lead also to obstruction of the common bile duct; therefore, jaundice has been seen in many cases of pancreatic colic. In one series,[20] 28 per cent presented this finding. With recurrent attacks of obstruction, the pancreas gradually undergoes atrophy and develops degeneration of the parenchyma. The first part of the gland to show this change is the acinar tissue. Only after some time are the islet cells also destroyed.

Oser[41] was able to find 24 of 70 cases (34 per cent) of pancreatic calculi showing diabetes. Other authors have reported an incidence of 40 per cent or more. A transient glycosuria may occur during an attack. Many cases show a diabetic type of glucose tolerance curve even though they do not spill sugar in the urine. These alterations in sugar tolerance at first are limited to the acute attack, but as damage to the pancreas progresses, and permanent changes set in, the diabetic tendency also remains constant. An improvement in the glucose tolerance curve and a disappearance of glycosuria has often followed operative intervention for pancreatic calculi. Painful diabetes should be a warning to search for pancreatic stones. In advanced stages of degeneration of the pancreas secondary to calculi producing obstruction, fatty changes of the liver often develop, apparently the result of loss of lipocaic from the destruction of the pancreas.[49] Many of these patients present multiple scars on the abdomen as evidence of misdirected and unsuccessful operations, the result of mistaken diagnoses. There is little to find specifically on physical examination of these cases. Occasionally a mass develops in the upper abdomen during an acute attack as a result of obstruction of the pancreatic duct. In some the pancreas may be outlined as a firm mass, perhaps somewhat tender. Fever, chills and leukocytosis may or may not accompany an attack. The disturbance of sugar metabolism has been discussed above. Elevation of the serum amylase and lipase and urinary diastase during an acute attack has been recorded. By intubation studies the decrease in the amount of pancreatic secretion and in the enzyme content of it has been noted. These tests, however, are not very readily performed. The determination of increased fecal fat, however, is easily carried out.

Aside from the history and the character of the pain, by far the most important diagnostic measure available is that of roentgenologic examination. This should consist of a survey film of the abdomen, including both anteroposterior and lateral or oblique views. The pancreas lies transversely in the region of the first to third lumbar vertebrae, the tail rising much higher than the head, up to the 10th to 12th dorsal vertebrae. The lateral view confirms the position of the calcifications in relation to the spinal column. Since these stones are almost pure calcium they cast a denser shadow than most biliary tract stones. However, they may also be confused with renal calculi, calcified mesenteric lymph nodes and calcified plaques in the splenic vessels or aorta. A cholecystogram and a urogram or pyelogram should aid in establishing the location of the calcifications with relation to the biliary and urinary tracts. At

times a duodenal tube has been passed to outline the course of the duodenum and, therefore, also the position of the pancreas and any calcifications within it.

Many cases of pancreatic calculi have been missed because a barium meal has been given before any films were taken. The overlying stomach and intestinal shadows then obliterate most pancreatic calculi, though some may be seen above the lesser curvature of the stomach. Fluoroscopic examination alone may readily miss these stones, so all gastro-intestinal series should include a preliminary survey film before giving the barium meal.

Complications of pancreatic calculi—aside from the effects produced by interference with enzyme and hormone production—include the development of cysts, abscesses, carcinoma and hemorrhage. The cysts may vary in size with acute attacks. The abscesses may present on the abdominal wall or rupture spontaneously into surrounding viscera. Occasionally a stone has eroded into a vessel large enough to give rise to severe or even fatal hemorrhage into the gastro-intestinal tract.[15] A small percentage of cases show malignant change, but this does not necessarily bear any relation to the presence of the calculi.

The first case to be treated surgically was in 1876,[20] when a pancreatic abscess containing calculi was drained. The first successful removal of a pancreatic calculus was by Moynihan,[20] in 1902. There were very few cases treated surgically prior to 1920. Since then, this problem has been attacked with increasing frequency, and with very encouraging results. The recent operative procedures developed for resection of the pancreas for carcinoma have added confidence in attacking this organ. It is recognized that such cases can be done without the development of fat necrosis or fistulae.

The approach to the pancreas may be through the gastrohepatic or gastrocolic omentum or through the transverse mesocolon. The latter seems less desirable, and the integrity of the middle colic vessels must be carefully preserved. We feel that a transverse incision gives ideal exposure for easy visualization of the entire gland. The pancreas may be enlarged, normal in size or atrophic, depending on the stage of the disease. It is likely to be quite firm and rubbery, and has the appearance of an ear of corn (interlobar pancreatitis). The calculi often can be felt, giving a sense of crepitus as they are rubbed one against another. By dividing the pancreas the duct can be exposed. This is usually dilated and the stones can be removed through it. It may be necessary to divide the duct longitudinally in order to obtain adequate exposure. If the stones are multiple and diffusely scattered throughout the pancreas, subtotal resection, beginning at the tail, is the most satisfactory procedure. One should be able to pass a catheter into the duodenum at the conclusion of the dissection. Though we have never tried such a procedure, the injection of lipiodol through the catheter to outline the ductal system while the patient is still on the table might occasionally be of value in confirming the patency of the duct or demonstrating other calculi. The stones often become impacted as the duct passes through the duodenal wall, and it may be of value to mobilize the duodenum by dividing the lateral peritoneal reflection and,

thereby, expose the head of the pancreas better. Some have opened the duodenum in order to free a stone trapped at the ampulla of Vater. A catheter left in the pancreatic duct and cigarette drains in the lesser peritoneal cavity provide adequate drainage. No permanent fistulae have developed. The pancreatic fluid which escapes from the wound is almost entirely nonirritant to the skin. This is in striking contrast to that from duodenal fistulae and many biliary fistulae in which the pancreatic enzymes have been activated.

The over-all mortality for operative treatment of pancreatic calculi is about 18 per cent, though smaller series have obtained figures of 8 per cent, and less. The results have been very encouraging and surgery is now the treatment of choice for this condition in severe cases. In milder cases a diet low in carbohydrates and high in proteins and fat may decrease the demands on the pancreas to produce secretion and, therefore, diminish the severity and frequency of the attacks. Ephedrine sulfate gr. ⅜ during an attack is of value by decreasing the amount of pancreatic secretion. This drug may also be used in conjunction with the diet as a prophylactic measure.

During a 10-year period, from 1936 to 1945 nine cases of pancreatic calculi were admitted to the services of the senior author at three hospitals. All were explored. There was one death in this series, a mortality of 11 per cent. Of the remainder, only one was not definitely improved though some continued to have slight residual symptoms. A brief summary of these cases follows:

CASE REPORTS

Case 1.—T. McG. (25092): A 38-year-old white male was admitted because of weight loss, severe epigastric colic, and diarrhea for six years. He showed steatorrhea, glycosuria and hyperglycemia. Roentgenograms revealed many pancreatic calculi. These were removed. His diarrhea disappeared; his insulin requirement dropped from 40 to 15 units. Though he subsequently took raw pancreas for a time he has since found that unnecessary, and now is entirely asymptomatic.

Case 2.—R. M. (48644): Admitted because of acute upper abdominal pain. Studies revealed a pancreatic calculus. There was no glycosuria. The stone could not be located at exploration. The duct was not opened, however. She had no postoperative pain.

Case 3.—F. E. (59445): A 49-year-old white man was admitted because of recurrent attacks of severe epigastric pain for eight years. Roentgenograms showed several pancreatic calculi. There was no glycosuria. Several stones were removed from the dilated duct. He has obtained marked relief from operation.

Case 4.—E. S. (59784): A 46-year-old white man was admitted because of epigastric discomfort, anorexia and weight loss. An epigastric mass was previously drained elsewhere as a pancreatic cyst. At operation here, partial pancreatectomy was done, with removal of several stones from the head of the pancreas. He was well for six weeks and then developed recurrence of pain and marked diabetes eventually. A more extensive pancreatectomy was performed and further stones removed. He did not recover from the operation.

Case 5.—E. S. (63562): A 43-year-old white woman was admitted because of recurrent attacks of severe upper abdominal pain and weight loss. Roentgenograms showed pancreatic calculi. Partial pancreatectomy and removal of calculi was done. After four months the drainage tract was reopened, but subsequently closed again. She has been much improved. She has been much improved.

One year after operation she developed weight loss associated with a diarrhea of 10

to 20 movements a day. On vitamin therapy and pancreatic extract, the diarrhea was controlled; she regained her weight and has an excellent appetite.

Case 6.—E. D. (63983): A 40-year-old white woman was admitted because of acute pancreatitis. A survey film showed several pancreatic calculi. At operation, several areas of frank hemorrhagic necrosis were found and drained. The pancreas sloughed-out in part. Subsequent films showed disappearance of calculi. The patient has had no further symptoms.

Case 7.—C. S., a 65-year-old white man was admitted because of recurrent epigastric colic. A nonfunctioning gallbladder and several pancreatic calculi were shown roentgenographically. Cholecystostomy was done and several gallstones removed; also one pancreatic calculus.

Case 8.—V. B. (125): A 52-year-old white woman was admitted because of abdominal pain, nausea, vomiting and weight loss for several years. Roentgenograms showed pancreatic calculi, several of which were removed at operation. She has continued to have pain since then and uses opiates. This patient was a morphine addict, with several hospital admissions before her diagnosis was finally made.

Case 9.—J. S., a 57-year-old white man was admitted because of acute upper right quadrant abdominal pain, subsequently diagnosed acute cholecystitis. Celiotomy did not relieve him. He was later operated upon for intestinal adhesions, without relief. On his third admission, when his roentgenograms were reviewed, shadows of pancreatic calculi were noted. At operation, a dozen stones and two-thirds of his pancreas were removed. A fistula presented when the drain was removed. The fluid discharge was clear and did not irritate the skin—the usual state of affairs if no bile is mixed with the pancreatic fluid. Recovered. An incidental finding was a gumma of the spleen.

Sixty-six cases from the literature were reviewed, and from these the data in Table I were compiled:

TABLE I

	No.	Percent
Average age	43	
Sex:		
Male	44	67
Female	22	33
Duration of symptoms (average)	7 yrs.	
Pain	55	83
Colic	35	53
Nausea	32	49
Vomiting	29	44
Diarrhea	15	23
Fatty stools	13	20
Jaundice	10	15
Alcoholics	17	26
Weight loss	33	50
Tuberculosis	5	8
Diabetes	33	50
Carcinoma	3	5
Solitary calculus	6	9
Gallstones	7	10
Preoperative roentgenographic diagnosis	34	52
Shadows seen above lesser curvature of stomach	7	10

SUMMARY

(1) Pancreatic calculi occur much more commonly than is generally appreciated.

(2) They can readily be recognized by roentgenologic examination.

(3) Surgical relief can be obtained, and this is the procedure of choice in severe cases.

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NOTE: Since this article was submitted for publication, other papers have appeared which are not included in the bibliography above. We would like to call attention especially to the paper, "Radical Surgery for Certain Cases of Pancreatic Fibrosis Associated with Calcareous Deposits" by Allen O. Whipple, in the ANNALS OF SURGERY, vol. 124: 991–1008, December, 1946.

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CYSTADENOMA OF THE PANCREAS

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CYSTADENOMA OF THE PANCREAS is an uncommon lesion. In a review of 6,708 autopsies at Guy's Hospital, in 1897, White found only three cases of pancreatic cyst, none of which was cystadenoma. Fitz, reporting a case, in 1900, commented upon the uncommonness of the lesion. From most reports since, its infrequency can be inferred, and Slattery, Boyd, Neef, Rabinovitch and Pines, and Brunschwig make specific reference to the rarity of the lesion.

The actual frequency of occurrence of pancreatic cystadenoma is difficult to estimate because cases are buried in the literature in general discussions of diseases of, or surgery of, the pancreas, and many cases of multilocular cyst of the pancreas of other varieties are undoubtedly falsely included as cystadenoma through inadequate pathologic study, misinterpretation, or unsatisfactory material. Mahorner and Mattson point this out stating that multilocular cysts are not necessarily cystadenomata, and that the meager descriptions so often found in the literature make it difficult to accept many cases as such. Hence, we get varying reports of the incidence of the lesion. Thus, Gruber quotes Yamane as having collected 37 cases up to 1921, while Hueper, in a report of one case, in 1928, states that only 24 cases had been recorded in the literature up to that time. Subsequent to 1928, only individual cases and small series are found in the literature. One case was reported by Maes in 1931, two cases by Janes, one by Carter and Slattery, and one by Pettinari in 1936, one by Neef in 1939, five by Bowers, Lord and McSwain (of which one was unproved), and two by Rabinovitch and Pines in 1942, and one by Beloff in 1945. In 1942, Brunschwig reported four cases from the University of Chicago Clinics and estimated that there were about 50 cases to that date.

Another approach to the frequency of occurrence of cystadenoma of the pancreas is through the incidence of the lesion in studies of large series of autopsies, operative cases, or hospital admissions. Here, again, a wide variance is found. Priesel, in 1922, reported that he had found nine cases in a review of 9,000 autopsies. Adams and Nishijima, in 1946, reported that the diagnosis of pancreatic cyst had been made at the Lahey Clinic only nine times from 1926 to 1945, and none of these were cases of cystadenoma. In 1921, Judd reported 41 cases of pancreatic cysts of all varieties gleaned from the records of the Mayo Clinic up to that date. The incidence of cystadenoma, or of the various other types of pancreatic cyst, is not given as it was impossible because of the degree of tissue destruction in many cases to tell whether they were dealing with a true or pseudocyst, or if a true cyst, what its exact nature was. In 1931, Judd, in conjunction with Mattson and Mahorner, published a second report on 47 cases of pancreatic cyst operated upon in the interval, the total of 88 cases having been obtained from 723,397 patients seen at the Mayo

Clinic in the corresponding period. No figures are given in this paper for the frequency of occurrence of the various types of pancreatic cyst but in another paper, later in the same year, Mattson and Mahorner state that two cases of cystadenoma were found in 108 cases of pancreatic cyst, which included these 88 and 20 others found at necropsy. Walters and Cleveland, in a report in 1939, state that 22 patients with pancreatic cyst were operated upon at the Clinic between 1935 and 1939. Thigpen, who analyzed the data on pancreatic cyst for a University of Minnesota Graduate School Thesis, is then quoted to the effect that from 1908 to 1939, 139 patients with pancreatic cyst were treated surgically at the Clinic, or one for every 8,000 patients registered. Of 55 of the 139 cases in which adequate tissue was available for study, seven were cystadenomata. In a later article, in 1945, Walters and Clagett repeat the previously-stated incidence of pancreatic cyst as one in 8,000 patients registered, with two cystadenomata in 88 cases of pancreatic cyst. While this probably does not exhaust the literature, it is sufficient to indicate the impossibility of arriving at any definite knowledge of the actual incidence or total number of cases reported. However, the uncommonness of the lesion is indicated with sufficient unanimity to warrant both the report of an additional case and a discussion of the special features characterizing cystadenoma of the pancreas.

All authors seem to agree that cystadenomata of the pancreas are true proliferative tumors. Robson and Moynihan classify pancreatic cysts as retention cysts, proliferative cysts, congenital cystic disease, hydatid cysts and pseudocysts. Proliferative cysts include cystadenomata and cystic epitheliomata. Boyd's classification omits hydatid and hemorrhagic cysts, but is otherwise essentially the same. McWhorter (after Oser) develops a detailed classification on the same fundamental structure, including cystadenomata among the cystic neoplasms or proliferative cysts. Brunschwig omits cystadenoma and cystadenocarcinoma from his classification of pancreatic cysts, preferring to consider them in a separate category of true neoplasms. Other minor variations are found consisting essentially of the addition of individual pathologic types, such as dermoid cyst by Judd, inclusion cyst by Rabinovitch and Pines, cyst with carcinomatous degeneration by Kennard, and cystic hemangio-endothelioma, cystadenocarcinoma of the islets of Langerhans, cavernous hemangioma, sebaceous cyst, and cyst of an accessory pancreas, by Walters and Cleveland. The basic classification, however, remains unchanged, with the general acceptance of cystadenoma as a true tumor or new growth similar to corresponding tumors of the ovary. A representative classification that is both inclusive, and simple, is that of Walters and Clagett. On an etiologic basis they classify pancreatic cysts as:

1. Cysts resulting from defective development:
   (a) Cysts among infants.
   (b) Cysts associated with polycystic disease of the kidney.
   (c) Dermoid cysts.
   (d) Inclusion cysts.

2. Cysts resulting from trauma (pseudocysts).
3. Retention cysts.
4. Neoplastic cysts:
   (a) Cystadenoma.
   (b) Cystadenocarcinoma.
   (c) Teratomatous cysts.
5. Cysts resulting from parasites.

While it is agreed that the tumors are true neoplasms arising from a disturbance in ontogeny, the exact locus of the disturbance remains obscure. Priesel believes that the tumors arise by the proliferation of the cylindrical epithelium of the pancreatic ducts, such proliferation going on to the formation of cystadenomata, or even adenocarcinoma. He adds that most authors believe that cystadenomata of the pancreas are due to aberrant pancreatic tissue which has become isolated. Lazarus describes many stages in development from simple dilated ducts. Archibald describes them as true tumors arising from parenchymal cells by proliferation. Rabinovitch and Pines also refer to cystadenomata as true pancreatic tumors arising from the parenchyma. Judd states that they form as do the cystadenomata of the thyroid or ovary; they are papillary ingrowths or adenomatous cysts. Gruber raises the question of duct proliferation on an inflammatory basis but it is generally agreed that this is not the case with cystadenomata. It is also suggested that the tumors originate from primordial cells displaced in early embryonic life, but opinions vary as to which embryonic tissue is involved. Displaced cells of the primitive urogenital fold having their origin from the segmentation cells of fetal life (the strayed genital cell theory), remnants of the mesonephros, and abnormal budding-off from the primitive gut have all been proposed as the original source. Carter and Slattery discuss the various embryonic sources hypothecated, and conclude that the type of tumor with cells closely resembling pancreatic tissue probably originates from displaced alimentary canal primordia. while cystadenomata with no resemblance to pancreatic tissue probably arise from strayed genital cells of the urogenital fold or from remnants of the mesonephros.

Grossly, the cysts vary in size and external and internal appearance. Ordinarily, cystadenomata do not reach the large size frequently encountered in other types of pancreatic cyst, although quite large ones have been reported. Fitz' case, for instance, was the size of a squash, Pringle's the size of a football, Beloff's the size of a grapefruit, Kennard's 15 cm., Dragstedt's (included by Brunschwig) 15 cm., and two of Bowers' cases were 15 and 18 cm., respectively, in their longest diameters. Characteristically, cystadenomata are rounded tumor masses with coarsely lobulated surfaces, although the larger ones are occasionally smooth-walled. Brunschwig speaks of their resemblance to a dense cluster of grapes. Encapsulation may be complete, although, as in our case, the cyst may be demarcated from the surrounding tissue without definite encapsulation. On section, they are almost always multilocular. The locules, or cyst spaces, are usually quite numerous, and may have a honeycomb appearance. They vary greatly in size, from less than a centimeter to as much

as 8 cm., but are inclined to be small. The contents of the cysts vary from thin, clear, turbid, or hemorrhagic fluid to viscid, mucoid or gelatinous material. The fibrous stroma between the locules may be scarce or abundant. Broad bands of hyalinized connective tissue, resembling the corpora albicans of the ovary, may be present, and in our case there was a central mass of fibrous tissue in which calcium had been deposited.

Microscopically, the cysts are lined, characteristically, by a single layer of epithelium. The cells may be cylindrical, like those of the pancreatic ducts, but more frequently are cuboidal or flattened. The flattening may even be more extreme so that the cells resemble endothelial cells to a degree that may lead to some doubt as to whether the tumor may not be a lymphangioma or hemangioma. Bloodgood, describing the histology in Finney's case, states that MacCallum, who also examined the slides, thought the tumor to be a lymphangioma, and one pathologist, reviewing the slides of the case reported here, was struck by the resemblance of the microscopic picture to that of hemangioma.

The cytoplasm of the cells is clear, the nuclei basal. The epithelial lining may be thrown into papillary projections or may dip down into the wall of the cyst in the form of a gland. In almost all cases, however, the single epithelial layer is maintained, although the heaped-up epithelium in the papillary folds may seem to show several layers. The presence of several layers may, according to Gruber, be an indication of malignancy. However, in Neef's case, about 3 per cent of the cyst cavities showed an epithelial lining 2 to 5 cells deep. In many cases the arrangement is similar to that of cystadenoma of the ovary, or even of the breast, and Bloodgood remarked on the resemblance of Finney's case to a breast cystadenoma. The stroma between the cyst walls is of variable thickness and may consist of a thin layer of loose bands of connective tissue or of broad, dense, hyalinized connective tissue septa which in our case contained bony spicules. The surrounding uninvolved pancreatic tissue is usually normal. In Pettinari's case there was an associated acute pancreatitis for which operation was performed, but Pettinari felt that there was no casual relationship.

It is important to point out that the differentiation between cystadenoma and other varieties of multilocular cyst of the pancreas (retention cyst) cannot always be easily made and sometimes may be impossible to make. Brunschwig emphasizes this point and other authors make it by inference. Usually, the cyst spaces in cystadenoma are multitudinous and small, with or without a few large ones, while those of multilocular cysts are relatively few and larger. Also, the cysts as a whole are usually larger than cystadenomata. The epithelial lining may be similar in both but its absence in large locules favors the diagnosis of multilocular cyst.

Malignant forms are much more rare than the benign ones. In distinction to papillary cystadenoma of the ovary, Kennard feels that malignant proliferation of a benign cystadenoma of the pancreas is rare. However, malignant change does occur, and Lichtenstein states that he feels justified in assuming

that his case of papillary cystadenocarcinoma started as a benign cystadenoma as the patient was known to have had the mass for six years and during that period was free of both symptoms and anemia, in addition to which, microscopy after its removal showed portions of the tumor with the structure of benign cystadenoma without any evidence of cellular atypism. Maes' case of benign cystadenoma showed occasional areas in which an infiltrative tendency was apparent, and one of Brunschwig's cases, in which the microscopy showed a benign cystadenoma, grossly infiltrated the duodenum requiring pancreaticoduodenectomy. Fitz called his tumor a multilocular cystadenoma but thought it was on the borderline between proliferative cystoma or cystadenoma, and cystomatous carcinoma. Carter and Slattery express the opinion that cystadenoma may give rise to cystadeno-carcinoma and that the pathology in some cases may be borderline.

The most common site of pancreatic cystadenoma, according to Heiberg, Robson and Cammidge, and Walters and Cleveland, is in the tail. Conversely, Lazarus states that the rarest site is the head of the pancreas. Again, it is difficult to compile accurate figures, but in the available literature only a few cystadenomata of the head are found while the remainder, comprising the vast majority of the tumors, seem to be about equally divided between the body and tail.

In growing, the cysts usually present between the stomach above and the colon below, covered anteriorly by the gastrocolic omentum. Occasionally, they present above the stomach in which case the anterior covering is the gastrohepatic omentum. Rarely, the direction of growth is between the layers of the transverse mesocolon with the cysts presenting behind or below the colon, or, they may extend upward or downward retroperitoneally.

Cystadenoma of the pancreas is much more common in females than in males. The symptomatology is that which one would expect of a slowly expanding lesion arising from the pancreas and is of course the same as that of any variety of pancreatic cyst. Pain is the most common subjective symptom. The location of the pain will vary with the location of the cyst and the structures upon which it impinges. Obviously, a cyst may be "silent" for a considerable period. When pain is experienced it may occur in any quadrant of the abdomen although usually it is in the upper abdomen and most often in the left upper quadrant. Occasionally it is referred to the back. The quality of the pain varies from a sense of fullness or a dull ache to severe relatively steady pain or sharp abdominal cramps. Radiating abdominal pains from pressure upon the celiac ganglion have also been described. Other symptoms result from pressure upon the neighboring organs, especially the stomach, and include anorexia and epigastric discomfort after meals, or nausea, vomiting, belching, gaseous distention, and constipation. Frequently these may be the only symptoms. Slight jaundice was encountered only once, in one of Janes' cases, the rarity being due to the rareness of the location of cystadenomata in the head of the pancreas. Weakness and weight loss are occasionally seen due to interference with nutrition, or uncommonly, to malignant degeneration.

The only significant physical finding is a palpable mass which in those of large size the patient may have noted himself. The mass is usually in the upper abdomen, in most instances to the left of the midline. In the large cysts it is likely to be tense and smooth, possibly cystic to palpation. The smaller ones usually cannot be palpated with sufficient definition to determine their characteristics. When arising from the body of the pancreas the mass is usually immobile. If the site of origin is the tail it may be freely movable, and occasionally, as in the case reported here, there may be considerable mobility when it arises from the head. Fluctuation can occasionally be demonstrated in the larger tumors. Laboratory data is of little assistance unless the external secretion of the pancreas is interfered with, in which case there will be an increase in fat, starch, and muscle fibers in the stools.

Roentgenograms are frequently of great assistance in diagnosis. The presence of a compression defect in the stomach, duodenum or transverse colon, an enlarged duodenal loop, or the displacement of the viscera, offers additional presumptive evidence when added to the other diagnostic data. The deposition of calcium in the cyst wall may, in rare instances, make it visible in the roentgenogram. Pneumoperitoneum and intravenous pyelography offer further aid.

Pancreatic cyst must be differentiated from mesenteric cyst, which usually has greater mobility particularly in a transverse direction and is generally prominent in the region of the umbilicus, from omental cyst which is usually very mobile and situated lower in the abdomen, and from ovarian cyst, hydatid cyst of the liver, fluid tumors of the kidney, giant hydrops of the gallbladder, retroperitoneal cysts, cysts of the posterior gastric wall or spleen, aneurysm of the abdominal aorta, and abscess of the pancreas. The differentiation of cystadenoma of the pancreas from other types of pancreatic cyst cannot usually be made clinically, and frequently the diagnosis of pancreatic cyst itself can only be made through surgical exploration.

Treatment, wherever possible should consist of surgical extirpation. This cannot always be effected because of the intimate relation of the cyst to important surrounding structures which would make their injury inevitable. The portal vein, common bile duct, splenic vessels, and superior mesenteric vessels may be intimately adherent to the cyst rendering its removal unduly hazardous. Serious hemorrhage may also be encountered, and Whipple states that one should be certain before attempting removal that it can be accomplished as otherwise serious damage may result. Nevertheless, with modern advances in surgery the operability has been considerably broadened. An excellent operative review is given by Brunschwig. Whenever feasible, he advocates incision through pancreatic tissue just beyond the gross limits of the bulging tumor surface with an effort to establish a cleavage plane. The tumor may then come away almost as though by enucleation. In Carter and Slattery's case the junction of the cyst to the surrounding pancreas was so dense that a cleavage plane could not be established and the cyst was removed by subcapsular dissection. Large cystadenomata of the midportion of the body

of the gland replacing all or most of the thickness of the pancreas should be excised by transection and ligation of the body of the gland to the right of the tumor which is removed together with the uninvolved pancreas distal to it. There should be no hesitancy about performing splenectomy where necessary. Nothing is accomplished by leaving a small uninvolved portion of the tail, as carbohydrate metabolism can be adequately maintained when only the head remains. Cystadenomata of the head should be excised leaving as much of the neck and body as possible. Even when deeply embedded, excision through normal parenchyma should be attempted. Injuries to the common bile duct and main pancreatic duct can be repaired if they occur. Rarely, partial resection of the duodenum may be necessary and radical pancreaticoduodenectomy can be considered as a final recourse.

Marsupialization, a common method of surgical treatment in other varieties of pancreatic cyst, is not a method of choice in the characteristic cystadenoma because of the numerous noncommunicating small cysts which would render treatment by this method inefficacious. In the occasional case it may be applicable, but even in these it has not been entirely satisfactory because of the persistence of external drainage for prolonged periods and occasional additional complications, such as infection of the sinus and cyst, formation of a secondary abscess, and excoriation of the skin by the drainage. Methods to eradicate the fistula and the lining of the cyst have, on the whole, been unsuccessful.

Internal drainage, by anastomosing the cyst to the stomach, duodenum, jejunum, or gallbladder eliminates the objection of fistula formation, but is subject to the same inapplicability as marsupialization in the average case of cystadenoma. Adams and Nishijima recommend cystojejunojejunostomy which they performed with satisfactory results in two cases of pancreatic cyst, but both the external and internal drainage methods are clearly more suitable for types of pancreatic cyst other than cystadenoma, not only because of the common multilocular architecture of the latter which would render drainage methods ineffectual but also because of the occasional malignant alteration which occurs. Accordingly, every effort should be made to extirpate cystadenomata completely. Irradiation, as far as is known, is without benefit.

The prognosis with complete extirpation should be good. Without surgery, growth may be so slow that no symptoms may develop for many years. However, with more rapid growth, symptoms of marked mechanical disturbance may occur, and the possibility of local infiltration into neighboring organs and of malignant change must be kept in mind.

Case Report.—No. 66173, Doctors Hospital: Mrs. I. B., age 31, a private patient of Doctor Samuels, was admitted January 16, 1946, for surgical exploration. She had been studied thoroughly prior to admission. About one year previously she had had occasional lower abdominal cramps which lasted for short intervals for about two weeks and then subsided. In November, 1945, she again developed occasional lower abdominal cramps which became more persistent and more severe. They usually occurred after the evening meal, but also sometimes during the day, starting in the midepigastrium as dull cramps and radiating across the lower abdomen, usually most marked in the left

lower quadrant. There was no relation of these pains to bowel movements, which were regular and without bleeding. Sometimes they were accompanied or followed by slight nausea, but there was no vomiting. Relief was usually obtained by lying down or hot drinks. Moderate relief was also afforded by antispasmodic and sedative medication. The appetite was excellent, the digestion good and there were no night symptoms, specific periodicity or relief by food. The cramps were also unrelated to menses or urination. Fifteen pounds in about two months were lost on a reducing diet, but on discontinuation of the diet several pounds were readily regained. Some fatigue was also present for the same period but this was blamed upon worry, and the care required by her two young children. Her sleep was undisturbed but inadequate. The remaining history was noncontributory.

Physical Examination.—This revealed a well-developed and well-nourished young female, appearing in good health. In the midepigastrium a slightly tender, slightly irregular, firm mass, about the size of a tangerine, was palpable. The mass was intra-abdominal, and freely movable, particularly from side-to-side. It moved with respiration, and could be made to disappear under either costal margin. The aortic pulsations were transmitted through it. The physical examination was otherwise negative except for a small fibroid in the right horn of the uterus and some scarring of the left parametrium.

Laboratory Data.—The blood count and sedimentation time were normal, the urine, stool and blood Kahn negative. The Rehfuss test meal showed an anacidity, but there was a positive response to histamine—excluding a true achlorhydria. The electrocardiogram showed low voltage in Lead I and late inversion of the T-wave in Lead IV, the observed changes being considered of no significance. Fluoroscopy of the stomach and duodenum showed a J-shaped, ptosed stomach completely visualized just to the left of the midline. The mass was felt to be to the right of and above the duodenal bulb but the duodenal bulb filled completely and the stomach showed normal peristalsis and antrum formation. There were no signs of pressure upon the antrum or duodenum. Barium enema showed a normal colon and terminal ileum. A plain film of the abdomen showed both kidneys of normal size, shape, and position, and no evidence of biliary or urinary calculi.

Because of the marked mobility, and the absence of significant roentgenologic findings, mesenteric or omental tumor, or pedunculated extrinsic lesion of the stomach were the diagnoses that were entertained.

Operation.—The patient was explored, January 17, 1946, through a right epigastric paramedian muscle-splitting incision (Doctor Jemerin). The mass was seen to occupy the head of the pancreas within the curve of the duodenum, the free mobility noted on examination being due to an unusually movable duodenum and pancreas. The mobility was so great that the duodenum could not only be reflected far medially leaving the mass to the right of it, but both duodenum and pancreatic mass could almost be delivered into the mouth of the wound. Both the paraduodenal peritoneum and the gastrohepatic omentum were incised, completely mobilizing the duodenum and exposing the head of the pancreas. The mass was then seen to occupy almost the entire head of the pancreas, only a thin rim of pancreatic tissue being identifiable as such on its posterior aspect. There was no definite capsule although the mass seemed circumscribed. The common bile duct, portal vein, and hepatic artery, which were identified in the free edge of the lesser omentum seemed to disappear into the posterior surface of the mass. It did not seem at first as though the mass were resectable without injury to the common duct, portal vein or hepatic artery and a radical resection of the head of the pancreas and duodenum was considered. However, it was decided first to make an effort to dissect the mass free, because of the high mortality and morbidity associated with radical pancreatico-duodenal resection. Accordingly, the common bile duct was again approached and freed up to the point where it seemed to disappear into the mass. Dissection revealed it to be flattened-out and closely applied to the posterior surface of the mass, or rather shell of pancreas, bound to it by areolar and fibrous tissue, and with further dissection its

separation was effected and its entrance into the duodenum seen. In similar fashion, the portal vein and hepatic artery were liberated from the tumor. With these out of the way, the tumor itself could be safely attacked. While there was no definite capsule, a zone of demarcation from the shell of the pancreas could be identified, and this was developed by sharp dissection until removal of the entire tumor was effected. The structures of the hepatic trinity were seen to be uninjured upon completion of the resection. Some oozing was encountered from the bared surface of shell of pancreas and this was controlled by a running catgut suture. Drainage was established down to the head of the pancreas through a stab counter incision in the right flank. The wound was closed in layers.

FIG. 1.—Gross specimen.

The postoperative course was entirely uneventful. Shortening of the drain was begun on the 3rd postoperative day and complete removal was effected by the 5th day. The patient was dicharged from the hospital in excellent condition on the 8th day after operation.

The patient has been followed to date. She has no complaints, and her general condition is excellent. Physical examination shows a well-healed, soft, pliable scar. The abdomen is soft and nontender, and there are no masses palpable. Fluoroscopy shows the duodenum to have returned to its normal position to the right of the midline.

Pathologic Report.—The tumor, in the gross (Fig. 1), was a firm, globular, nodular mass, about 10 cm. in diameter, the nodular surface being due to numerous small cysts presenting externally. On cut-section (Fig. 2) multiple small cysts separated by a dense stroma of variable width were seen. The cysts averaged between 0.25 and 1.0 cm.

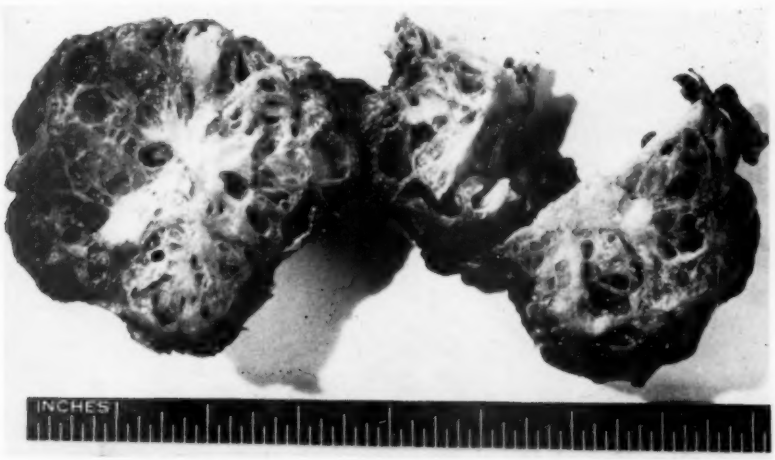

FIG. 2.—Gross specimen, cut-section.

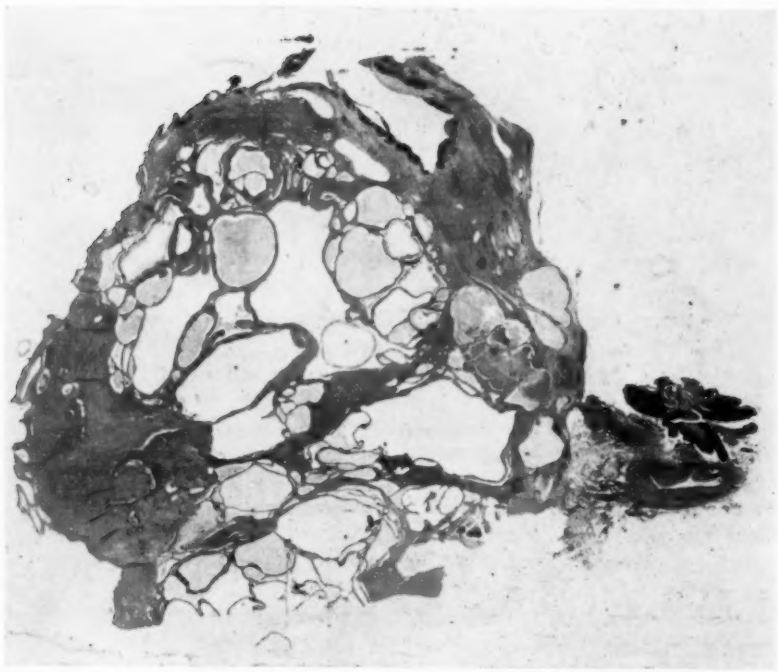

FIG. 3.—Photomicrograph (x 4).

in size and were most numerous toward the periphery where a honeycomb appearance was suggested. The stroma increased irregularly toward the center of the growth, forming there a large solid central mass containing calcific deposits. The surface cysts were thin-walled and translucent; the deeper ones were embedded in increasing amounts of supporting tissue. Some contained gelatinous material, others bloody fluid.

Microscopically (Figs. 3 and 4), the main portion of the mass consisted of large channels (cysts) containing amorphous material or well-formed blood cells and some hemosiderin-bearing phagocytes. The cysts were lined by a single layer of epithelial cells

FIG. 4.—Photomicrograph (x 20).

which ranged from cuboidal to flat. The latter resembled endothelial cells to such a degree that, just as did MacCallum in Finney's case, one pathologist reviewing these slides was highly impressed by the similarity of the histologic picture to that of an endothelial tumor. The separating stroma consisted of dense hyaline connective tissue septa of varying width and rather cellular character. Small nests of hemosiderin-bearing cells were found within the connective tissue septa. The calcified area consisted of very dense hyaline tissue with fine bony spicules. At one periphery a small portion of pancreatic tissue was seen. *Pathologic Diagnosis:* Cystadenoma of the pancreas.

COMMENT.—A cystadenoma of the head of the pancreas which had compressed the residual tissue of the head into a thin shell intimately applied to its posterior aspect was successfully removed. The common bile duct, portal vein and hepatic artery which were flattened out and bound to the posterior aspect of the mass were dissected free. Of note was the absence of any evidence of common duct or portal vein obstruction despite the marked compression of these structures. The location of this tumor in the head of the

pancreas is uncommon in a lesion which in itself is infrequent. The mass was markedly mobile and because of this and the absence of any suggestive roentgenologic findings, a pre-operative diagnosis of pancreatic cyst was not made. The mobility was due to an unusually displaceable duodenum and pancreatic head. It was noted, fluoroscopically, that the duodenum was situated to the left of the midline but as there was no evidence of its compression or distortion, the significance of the finding was not interpreted as suggesting a pancreatic lesion. The tumor itself was firm rather than cystic to palpation, and on section there was a considerable fibrous stroma between the numerous small cysts with a large, central solid mass containing calcific deposits. The epithelium lining the cysts in some areas bore a marked resemblance to endothelium. It is interesting that despite this presence of calcium in the mass no shadow was cast on the roentgenograms even when the films were reviewed in retrospect.

SUMMARY

1. The literature on cystadenoma of the pancreas is reviewed, and the various clinical, pathologic and surgical features of the lesion are briefly discussed.

2. A case of cystadenoma of the head of the pancreas in a 31-year-old female, with successful surgical extirpation, is reported.

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MUCOCELE OF THE APPENDIX, WITH MYXOGLOBULOSIS*

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MYXOGLOBULOSIS is a special type of mucocele characterized by the presence of globoid bodies, 2–3 mm. in diameter, composed of mucoid material. They form clusters resembling frog eggs, which has led to the adoption of such names as "fish-egg or frog-egg mucocele."

The first case of mucocele with myxoglobulosis was described by Latham[10] (1897), who discovered the condition by chance in the course of a routine postmortem examination. Huetter[8] (1907) presented a case of pseudomyxoma peritonei which originated from a mxyoglobulosis of the appendix. Boeckmann[1] (1910), found a mucocele of the appendix with myxoglobulosis while operating for what appeared to be acute appendicitis. Von Hansemann[6] (1914) found this condition in two routine autopsies and gave it the name, "myxoglobulosis." Since that time a number of other cases have been reported. In 1941, Hollström[7] reviewed the literature and found 36 cases of mucocele of the appendix associated with myxoglobulosis. Since then only two other cases have been mentioned in the available literature. As to the frequency of ordinary mucocele and myxoglobulosis, only a few data are available. Neither in Castle's[4] 28 cases of cystic dilatation of the appendix, nor in Jirka and Scuderi's[9] 22 mucoceles found in 9,535 appendicectomies at Cook County Hospital, Chicago, nor in Mayo and Fauster's[11] 76 mucoceles, was any mention made of the presence of myxoglobulosis. In 1925, Milliken and Poindexter[12] stated that the incidence of myxoglobulosis in cases of mucocele was 0.35 per cent. To date, approximately 500 mucoceles, 39 with myxoglobulosis, have been recorded, to give an incidence of 7.8 per cent. However, there would be a tendency to report single cases of the latter, whereas the former would appear in the literature in larger series, thus, the true incidence of myxoglobulosis should be lower.

Case Report.—This patient, a while male, age 54, entered the Jewish Hospital, March 24, 1945, on the service of Dr. Alfred Goldman. His chief complaints at that time were swelling in both lower extremities and cramping (substernal) pain. After examination, diagnoses of cardiac decompensation, moderate arteriosclerosis, chronic nephritis, and chronic passive congestion of the lungs were made. Laboratory examination was negative except for a 2 plus albumin and an N.P.N. of 49. Decompensation therapy was instituted. On March 30, 1945, the patient developed nausea and an attack of abdominal pain, which seemed to be most severe on the right side of the abdomen. Examination revealed tenderness, rigidity and rebound tenderness over McBurney's point. There was no history of any previous attacks. Blood was noted in the stool on digital examination.

Laboratory Data.—W. B. C. 14,000; 5 stabs. Urinalysis: 2 plus albumin. Blood

* Aided by the Louis M. Monheimer Research Fund.

N. P. N. 49, diastase 61, total protein 6.6, albumen 4.5, globulin 2.1, cholesterol 239. Temperature 100° F., pulse 86, respirations 20. A diagnosis of acute appendicitis was made, bearing in mind the possibility of an acute mesenteric thrombosis and Meckel's diverticulum.

FIG. 1

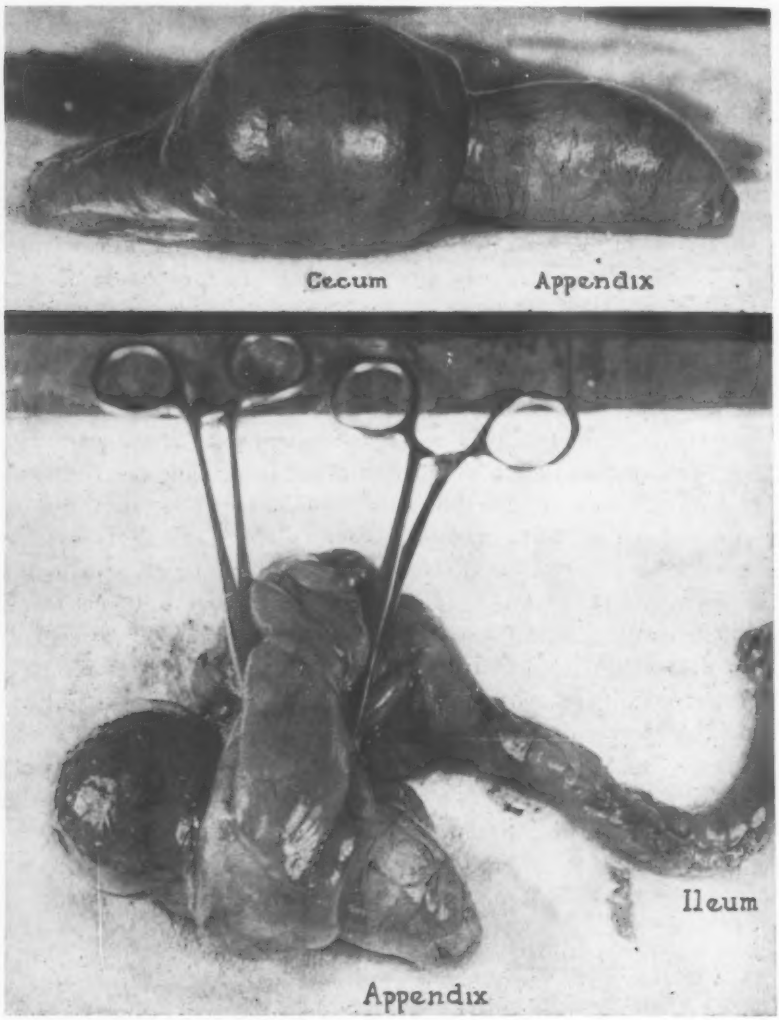

FIG. 2

FIG. 1.—Specimen removed at operation, showing the dilated distal end of the appendix and the proximal end intussuscepted into the cecum. (About two-thirds actual size.)

FIG. 2.—The cecum end opened, showing the intussuscepted mucocele. (About two-thirds actual size.)

Operation.—On exploration, a very large, elongated, injected organ resembling a distended gallbladder was encountered. Upon further investigation the gallbladder was found to be in its normal position and not diseased. The mass proved to be a large, distended appendix, which was partly intussuscepted into the cecum (Fig. 1). Because of

the patient's critical condition, the entire mass, including the cecum and ileum, was exteriorized and removed with a Rankin clamp. The abdomen was closed in the usual manner. The patient had a stormy postoperative course, but left the hospital well.

Pathological Report.—Gross: The specimen consists of a piece of ileum, the cecum, and a small portion of ascending colon. The appendix is transformed into an oblong sac, measuring 7 cm. in length and 3.5 cm. in diameter. The proximal one-third of the dilated appendix is invaginated into the lumen of the cecum and the portion of the cecal mucosa covering the intussuscepted sac is swollen and dark-red in color. The distal portion of the appendix is not involved in the intussusception and has a greyish, pale surface (Fig. 2).

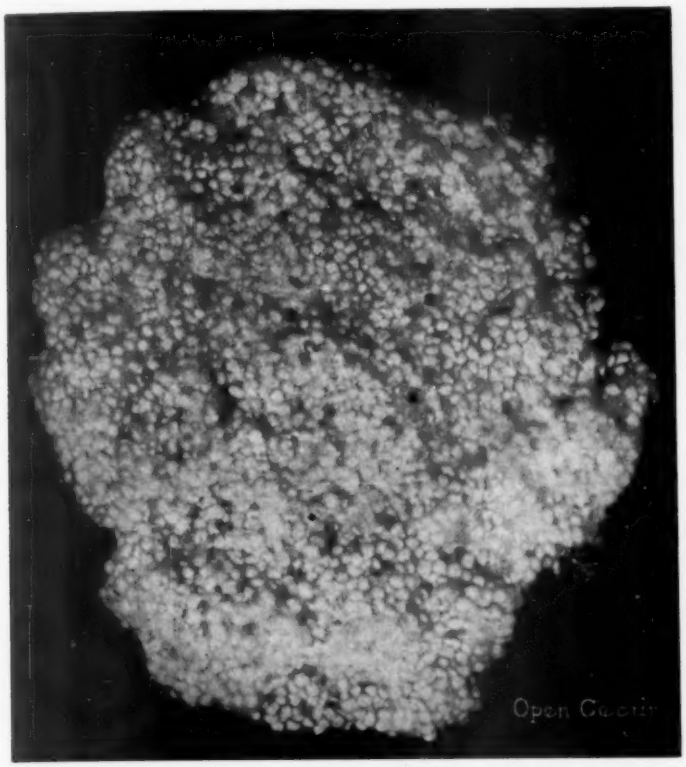

FIG. 3.—Contents of the mucocele composed of clusters of globoid bodies (actual size) spread out on a flat surface.

The distended lumen of the appendix contains about 80 cc. of jelly-like material composed of hundreds of opaque white globules, measuring about 2 mm. in diameter. Groups of them are glued together by a yellowish-white, mucoid material, creating the appearance of a cluster of fish eggs (Fig. 3). The wall of the dilated appendix measures 2 mm. in thickness; it shows no definite stratification.

Microscopically, section through the wall of the cecum, covering the intussuscepted appendix, shows the epithelial surface for the most part destroyed and the remaining areas covered by a deposit of fibrin and leukocytes. There is marked hemorrhage into the wall and infiltration of all layers by polymorphonuclear and mononuclear leukocytes. The serosa is also poorly preserved. Sections through the wall of the dilated appendix fail to show any lining epithelium, although deposits of mucoid material, with scalloped edges, suggest the outlines of intestinal glands. In one area the mucoid material appears to be actually deposited within the submucosa. The wall is thickened and consists of layers of

longitudinal and circular muscle, and remnants of a submucosa, with a few inactive lymphoid follicles. The globules forming the contents of the appendix, when stained with haemotoxylin and eosin, show an outer blue-staining, laminated hull and an eosinophilic center, which consists of finely granular material and contains numerous clear, linear slits (cholesterol slits). Examination of the fresh, unstained globules reveals typical cholesterol crystals. *Pathologic Diagnosis:* Myxoglobulosis of the appendix with intussusception into the cecum.

COMMENT.—The experimental work of Grodinsky and Rubnitz[5] has contributed considerable information concerning the etiology of ordinary mucocele. In 26 rabbits they ligated the proximal end of the appendix, carefully avoiding the blood supply and clearing, but not sterilizing, the lumen. They were able to produce mucoceles by this method almost at will. Rubnitz and Hermann[15] reported that of 24 mucoceles produced by this artificial method, two showed myxoglobulosis, but they were unable to give a satisfactory explanation for this variation. They suggested that probably a combination of physical effects, such as a particularly forceful peristalsis from the hypertrophic muscles, together with changes in internal pressure of the mucocele, are required to give this characteristic picture.

Pohl,[13] and Cagnette[3] believe that the same infection which results in the stenosis of the proximal end of the appendix also damages the glands. As a result, the orifices of some of the glands become stenosed and the secreted mucus is trapped. The mucous masses exert pressure on the epithelium, which becomes detached and accounts for the cellular elements often observed within the globules. Owing to reabsorption of water the secretions become inspissated, but they retain their globular shape. The pressure further increases, due to muscular action of the appendix, and the occluded glands finally burst, allowing the globules to escape and gain access to the lumen of the appendix. Here they coalesce with other globules and become rounded-off, in the same manner as rice bodies in a knee joint.

According to Poindecker[14] a phlegmonous type of inflammation occludes the proximal portion of the appendix with formation of a mucocele, which by pressure causes the appendiceal crypts to enlarge and to form small diverticula. The globules then develop in these diverticula by the same process as was described above.

Von Hansmann[6] points out that the appendiceal glands are hardly large enough to accommodate the globules, which measure up to 2 mm. in diameter. He suggests that only the nucleus of the globules forms in the glands and the outer layer is added in the appendiceal lumen, which is borne-out by the different staining properties of these two layers. However, by this same line of reasoning it might be pointed out that the nucleus of the globules (the eosin-staining portion) measures 0.5 to 1 mm. in diameter and could not be accommodated by an ordinary-sized appendiceal gland.

The pathologic findings in our case agree for the most part with the previous reports of mucocele with myxoglobulosis discussed in the literature. Destruction of the mucosa is a fairly constant finding, although Rubnitz and Hermann[15] describe a marked hyperplasia of the mucosa, with papillomatous

proliferation in their artificially-produced cases in rabbits. Undoubtedly this is an early reaction, which probably changes as the pressure within the appendix increases.

The chemical composition of the globules is still a matter of discussion. Most authors believe that the inner kernel, which stains red with eosin, is a pseudomucin, giving a negative test for mucin. It does not stain by the Weigert method for fibrin. The outer onion skin layer, on the other hand, stains with haemotoxylin, and not infrequently gives a positive test for mucin. Several authors have described cellular débris and epithelial cells as inclusions within the globules, but no mention is made of cholesterol crystals, as we found in the case reported above. They can easily be explained as products of cellular disintegration of the appendiceal mucosa. This would favor the theory that the globules begin their formation within the appendiceal crypts.

Based on all of the evidence available to date, we feel that the pathogenesis of myxoglobulosis is as follows: A very mild inflammation of the cecum or the proximal end of the appendix seals it off and produces a mucocele. The same process injures the glandular epithelium of the appendix and a number of epithelial cells are destroyed and sloughed-off into the lumen of the crypts. In addition, some of the mucinous material becomes inspissated in the appendiceal crypts, which enlarge as a result of increased pressure and the globules are formed. Intrinsic pressure from the globules within the crypts causes destruction of the epithelial lining and some of the cellular elements are included within the globules. When the globules grow too large for the crypts they are expelled into the lumen of the appendix, possibly with the help of peristalsis, and in the lumen they come in contact with the mucoid material present. Continued peristalsis rotates the globules and, thus, they collect layers of mucin and the outer shell assumes a laminated appearance. At the same time the remaining mucosal surface becomes further atrophied, due to the continued pressure within the appendix.

It is interesting that of the 38 cases of myxoglobulosis reviewed in the literature, only about six of these cases were operated upon for symptoms referable to the appendix. All of the others were discovered in the course of surgery for some other cause, or as findings in routine postmortem examinations.[2] Although several cases of intussusceptions related to simple mucocele appear in the literature, ours is the only case of intussusception caused by mucocele of the appendix, with myxoglobulosis.

SUMMARY

A case of mucocele of the appendix, with myxoglobulosis, associated with intussusception is reported.

Cholesterol crystals found within the globoid bodies, which have not been described previously, are considered indicative of destruction of epithelial cells in the crypts of the appendix. This débris together with inspissated mucus forms the nucleus of the globules, which later add to their size as they are expelled into the lumen of the appendix.

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CARCINOMA OF THE BREAST IN THE ABSENCE OF CLINICAL BREAST FINDINGS

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THE DETECTION of early malignant lesions of the breast is often impossible for the layman and even difficult for the physician because of the small size of the growth. More-and-more it has become apparent that the problem of breast cancer is a discouraging one and that the best hope for its successful treatment is early recognition and thorough eradication. The difficulty confronting the clinician in the early detection of this condition is evident from the report of the following cases.

Although these three cases were examined by several physicians, it was impossible to detect any clinical signs of pathologic abnormality in the breasts of any of the patients. If similar instances have been previously observed and recorded, a cursory review of the voluminous literature on carcinoma of the breast failed to reveal it.

CASE REPORTS

Case 1.—A female, age 62, was referred to the Clinic on April 21, 1943. The patient stated that two months prior to admission she had noticed a tumor mass in the right axilla. At first the growth was small and was described as bean-size; this had gradually enlarged until at the time of admission it appeared about the size of a hen's egg, and was deeply imbedded in the axilla and apparently attached to the axillary vein. The growth was firm and not freely movable. It appeared rather hard and nodular, and seemed definitely malignant, although the possibility of tuberculosis and Hodgkin's disease had to be excluded. A careful breast examination revealed no abnormality in either breast. There were no demonstrable lymph node enlargements elsewhere. The general physical examination was otherwise negative. A differential and complete blood count was normal. Roentgenologic examination of the chest was negative.

Operation.—On April 26, 1943, under gas-ether anesthesia the tumor mass was excised. It was adherent to the axillary vein and was hard and nodular and 6 by 4 cm. in size. It appeared grossly malignant, and this impression was confirmed by a frozen-section examination. The possibility of a malignant degeneration of a supernumerary breast was considered, and the prognosis was believed unfavorable.

Permanent tissue examination was reported by the pathologist, Dr. Henry Bunting, as follows: "Section shows carcinomatous metastases in lymph nodes, which one could casually assume were from the breast. If that possibility has been ruled out, there is some histologic evidence that the tumor may be from the large sweat glands of the axilla; if the mass appeared adherent to the skin, I should think that origin almost certain."

The mass did appear adherent to the skin, and, in the absence of any signs of pathologic changes in either breast, the condition was considered as a primary sweat gland tumor of the axilla. However, in the light of my experience since that time I would have made a different decision in regards to this case as may be judged from the following:

For the next six months the patient was given several treatments with radium packs to the axilla. From that time she returned for follow-up examinations every three months until August 27, 1946. She stated that two weeks prior to that date she had noticed a small lump in the right axilla. Examination revealed a recurrent, hard, nodular, fixed mass deep in the right axilla. However, at approximately 3 o'clock in the right breast, about 5 cm. from the nipple, there was a firm, hard mass about 3 x 3 cm. There was no retraction of the nipple, but the skin was attached. Thus, three years and four months after the removal of the axillary node mass the probable primary tumor became apparent in the breast. This tumor, of course, had been present in microscopic form for several years, but repeated clinical examinations of the breast by several physicians every few months failed to reveal any gross evidence of it.

From experience gained in the following two cases, in retrospect, I would have performed a radical breast amputation as soon as a pathologic examination had indicated that the axillary nodes were malignant. On August 27, 1946, a radical breast amputation was performed; however, it was impossible to satisfactorily clean out the axilla because of dense scar attachments to the axillary vein, the result of the previous operation and of the radium therapy. At the present time there is no other evidence of further metastasis, and the patient's health is good.

The pathologic examination showed "carcinoma of the breast, with considerable differentiation of cells."

Case 2.—On October 13, 1944, a 37-year-old single woman came to the Clinic because she had accidentally found a lump in her left axilla the day previous. Examination by Dr. Harold Marsh revealed a small movable mass that was hard and about the size of a marble. No other nodes were palpable, and careful examination of the breast revealed no evidence of any pathologic changes. A dissection of the axillary nodes was performed by Dr. Luther Holmgren, and the pathologic examination by Dr. Henry Bunting showed a metastatic cancer, adenocarcinoma in type, but becoming simplex. On the basis of this report is was decided to perform a radical amputation of the left breast, which was done on November 30, 1944. Gross examination revealed several minute areas suggestive of carcinoma in the lower portion of the breast as well as several small nodes. The patient received postoperative radiation therapy and, when last examined on September 3, 1946, was in good health.

Case 3.—On October 10, 1946, a married woman, age 50, came to the Clinic because of a lump in the left axilla first noticed some five months prior to admission. When first noticed, the lump was described as being the size of a marble, and no enlargement had been observed.

Examination by Dr. Harold Marsh revealed two discrete nodes in the left axilla. They were hard but movable. Physical examination including a careful study of both breasts was otherwise negative. A roentgenologic examination of the lungs was negative. On October 24, 1946, excision of the axillary nodes was performed, and the following pathologic report was given by Dr. D. M. Angevine: "Medullary carcinoma. Origin is not clear from data given. Unusual location for metastasis from carcinoma of lung, but this is a possibility."

In the light of the two cases reported above another very careful examination of the patient's breasts was made without revealing any abnormalities. Not satisfied, I called into consultation several of my associates, all of whom corroborated my findings. The experience with the other two cases was reported to the patient and her relatives, and despite the negative examination a radical removal of the left breast was advised. Consent for the same was given, and on October 29, 1946, this operation was performed. When the breast was removed and turned over, several suspicious areas the size of a match head could be palpated but scarcely distinguished from the surrounding tissue. There was one node that appeared involved. The pathologic report by Doctor Angevine was as follows: "Breast specimen consists of a breast with irregular, firm, gray bands radiating out from

the nipple and extending into fat. There is also a lymph node measuring 1.2 x 1 cm. that is very firm. On sections, there is a carcinoma of duct type, with extensive involvement of the lymph node. *Pathologic Diagnosis:* Carcinoma of breast, with metastasis to a lymph node."

The patient made an uneventful recovery and is now receiving radiation therapy.

These three cases illustrate the need of a careful examination of the axilla of all patients despite negative breast findings. If axillary nodes are found, they should be removed for pathologic examination, and, if found to be malignant, the advisability of a radical breast amputation should be given most serious consideration.

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HAMARTOMA OF THE LIVER

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HAMARTOMA OF THE LIVER, a distinctly rare entity, if judged by the paucity of cases reported, deserves mention when encountered because it represents a resectable and curable tumor in an organ commonly involved by hopeless neoplasms.

Hamartoma (*ἁμαρτία*, error or defect; and *-ωμα*, tumor) is a term coined by Albrecht[1] in designation of certain tumors which cannot be classified with the true neoplasms, which have a relative quantitative disproportion of tissue elements normally comprising the organ, but which have not attained the complete pattern of the organ. These tumors are congenital and of a teratoid nature, with retention of some embryonal characteristics; they are more or less encapsulated, do not contain mitotic figures and do not metastasize. In the indexed titles of the literature of the past ten years the term, hamartoma, has been used in connection with tumors of the skin, tympanum, brain, choroid plexus, thyroid, lung, bronchi, spleen, heart, mediastinum, and liver. Hamartoma of the liver is generally found in the infant. Ladd and Gross[5] described an hamartoma of the liver, weighing 400 Gm., successfully removed from an infant of eight months. Benson and Penberthy,[3] in 1942, excised a similar tumor, weighing 60 Gm., from the liver of an infant seven months of age with recovery.

Case Report.—No. 18591: R. O., white, female, age 16.5 months, was admitted on the Pediatrics Service of Memorial Hospital by Dr. J. Keller Mack, September 15, 1946, because of enlargement of the abdomen. She had been born by cesarean section because of postpoliomyelitic deformities of the mother, and had always appeared in normal health, though her abdomen was always noted to be large. No abnormality was detected by her family doctor until he found an abdominal mass about two weeks before admission.

Physical Examination: A well-developed child, weighing 24 pounds, and standing with moderate irreducible protrusion of the abdomen (Fig. 1). A rounded, partially lobulated, firm mass extended from the right costal margin into the iliac fossa, filled the right flank and extended across to the left nipple line, occupying about two-thirds of the abdomen. Examining fingers could be inserted beneath the costal margin, but the upper border of the mass was indefinite; the lower border was freely palpable, and the tumor could be moved slightly, with no apparent pain; it was less well-palpated through the flank.

Laboratory Data: Hemoglobin 11.5 Gm. (74 per cent); R. B. C. 3.99 million; W. B. C. 8,600; lymph. 58, seg. 32, stab. 21, eosin. 4, mono. 4. Urinalysis was normal.

Roentgenograms showed a large homogeneous mass in right side of abdomen. After barium enema the mass was seen to displace the proximal colon downward and posteriorly (Fig. 2). Intravenous pyelogram showed no dye in right kidney, but retrograde examination showed normal pelvis and calyces on right.

Course: After preliminary blood transfusion, and with a diagnosis of probable mesenteric cyst, operation was performed, September 21, 1946, under vinyl and ethyl ether inhalation anesthesia. Through a long right rectus incision the tumor was immediately encountered and delivered (Fig. 3). It measured 8 x 7 x 4 inches *in situ,* and in shape, size, consistency and color bore a striking resemblance to a beef heart; the base was broadly incorporated into the right lobe of the liver, and the medial border lay immediately adjacent to the gallbladder; the apex felt cystic; large veins coursed beneath the serosa of the tumor into the liver. Complete excision required resection of nearly half of the right lobe of the liver, which was accomplished without great difficulty by preliminary placement of mattress sutures of No. 1 chromic catgut; the lateral half of the resection was facilitated by temporarily compressing the liver with a rubber-shod intestinal clamp. The capsule of the tumor did not completely enclose the base where the tumor tissue blended with normal liver, but it was considered to have the gross characteristics of a benign lesion. Mild shock ensued during traction on the liver despite blood replacement; it was estimated that less than 200 cc. of blood was lost, but a similar amount was probably contained in the tumor. The raw stump was allowed to retract above the mesocolon without reperitonealization. The wound was closed with No. 0 chromic catgut for peritoneum and No. 30 cotton for fascia. A small Penrose drain was left inlying to the stump.

FIG. 1.—Preoperative photograph demonstrating enlarged abdomen.

The patient developed a rectal temperature of 104.2° F. eight hours after operation, and this gradually decreased to normal by the 8th day, when the drain and sutures were removed. Adequate urinary output was assured by intravenous solutions. Abdominal distention was present for three days. She was discharged on the 11th postoperative day. Examination five months after operation disclosed that her physical development had proceeded normally and there was no evidence of recurrence of the tumor.

Pathologic Examination (Dr. A. Vass).—*Gross:* A heart-shaped mass 17 x 17 x 9.5 cm., weighing 1,575 Gm. (Fig. 4A). On section (Fig. 4B), the entire mass consists of roughly lobulated, firm but elastic yellowish-pink tissue; the lobules measure from 2 to 5 mm. in diameter and are separated by septa less than 1 mm. in width. In the distal portion is a roughly spherical 8-cm. cyst containing clear yellowish fluid and lined by a smooth pinkish-gray transparent membrane with incomplete septa. Several similar but smaller cysts were found on further section. At the base a 3 to 4 mm. layer of reddish-brown liver tissue is noted to be well-demarcated from the adjoining tumor tissue.

Microscopic: The liver tissue present at the proximal end of the specimen appears to be quite normal. Very slight infiltration by round cells is present in periportal connective tissue. However, in the zone of the liver which adjoins the tumor mass (Fig. 4C) the periportal connective tissue contains rather irregularly-shaped glandular structures which

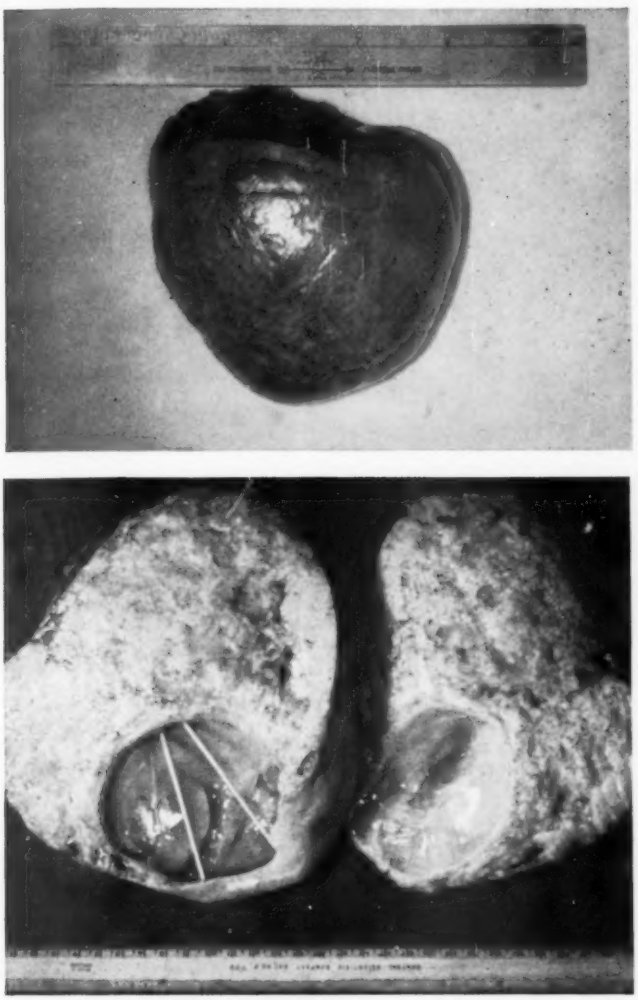
A B

FIG. 2.—Roentgenograms, A. anteroposterior, and B. lateral, demonstrating inferior and posterior displacement of right colon.

FIG. 3.—Appearance of tumor at operation. Hemostat indicates attachment to liver.

are more or less haphazardly arranged. They are lined by a single to double layer of cuboidal epithelial cells most of which possess vesicular and only occasionally hyperchromatic nuclei. Often these structures are surrounded by groups of lymphocytes and a few eosinophilic polymorphonuclear leukocytes. The structures are not always confined

A



B

FIG. 4.—Gross specimen: A. after excision, and B. after section, demonstrating cyst at apex.

to the periportal connective tissue but are also found between the adjoining liver cords. The structures are not infrequently surrounded by apparently newly-formed moderately cellular connective tissue. These structures resemble bile ducts in a general way. Sections from the periphery of the tumor (Fig. 4D) reveal it to consist of rather abundant, somewhat edematous, hyalin connective tissue forming the stroma into which are embedded

numerous glandular structures similar to those described above except that they are more irregular in shape and are somewhat distended. They contain traces of pinkish-staining homogeneous material. Occasionally there are papillary projections of connective tissue into the lumina. These projections are covered with cuboidal cells similar to those lining the lumina elsewhere. There are also a large number of rather distended capillary blood spaces lined with a single layer of flat endothelial cells. Occasionally the arrangement of connective tissue about these spaces is similar to that seen in veins. Small islands of polygonal, moderately large cells, possessing somewhat hyperchromatic moderately large nuclei and somewhat eosinophilic cytoplasms, are scattered throughout the section. These

FIG. 4C

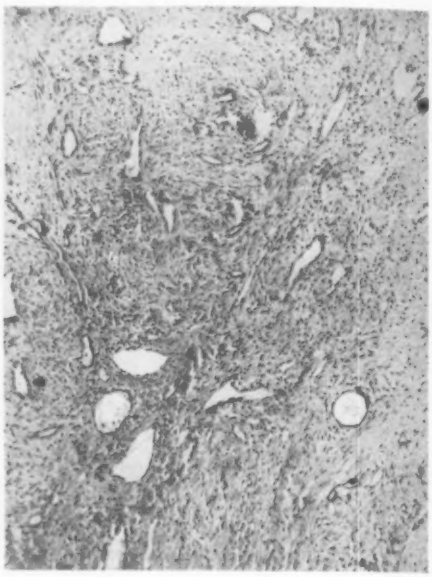


FIG. 4D

FIG. 4. (Cont'd.)—Photomicrographs demonstrating C. liver-like tissue near base of tumor, and D. fibrocystic appearance near apex.

resemble liver cells and sometimes are continuous with the above mentioned glands. *Pathologic Diagnosis:* Hepatoid hamartoma. A tumor of complex embryonal origin, probably arising from the multivalent liver cell, and possibly malignant.

DISCUSSION.—Sections from this tumor were reviewed by another pathologist* who agreed that it was classifiable as hamartoma under the present usage of the term, considered it benign but preferred a more descriptive term such as "benign mixed cystic teratoid tumor."

In a classification of true primary tumors of the liver, Warvi[10, 11] consid-tred hamartomas to be indistinguishable from adenoma of the liver, a more common and usually benign tumor. His opinion was based on review of material demonstrating a preponderance of liver cords without bile ducts or

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portal triads, a type of tissue not exactly comparable to our case nor to that of Benson and Penberthy who permitted the author to study their sections which resemble the proximal portion of the tumor here reported. Further case studies should be reported to permit a more precise classification of these tumors and to define their relationship to other benign tumors composed of hepatoid elements. It is possible that the variable criteria for the diagnosis of adenoma of the liver may have resulted in the classification of hamartomas with adenomas in other series.[8]

It would appear inaccurate to liken the tumor in our case to adenoma, cystadenoma or cholangiohepatoma as the proportions of liver cells, bile ducts and fibrous tissue varied within the tumor itself, there being, at the base (Fig. 4C), a less mature but more liver-like tissue than at the apex (Fig. 4D) where liver cells were scarce and fibrocystic tissue predominated. A comparable tumor removed from the liver of a 13-months-old infant and weighing 4.5 pounds was described by Lee[6] as "large solitary bile-cell fibro-adenoma of the liver." It is this abnormally great development of supporting connective tissue that is described by Albrecht[2] in his discussion of hamartoma and hamartoblastoma. In a former article[1] he regarded the two main possibilities of the manner of origin of fibrocanalicular hamartomas as: (a) abnormally abundant formation of connective tissue as a result of increased anlage or greater localized power of proliferation of mesenchyme cells; and (b) abnormal relative activity between the canaliculi-forming and the supporting tissue cells.

The tumor in our case weighed 1575 Gm., nearly five times the weight of the average liver of this age, which is said to be 331 Gm.;[4] and composed one-seventh of the patient's total weight.

These tumors apparently occur most often in the right lobe of the liver. Characteristic displacement of the colon downward and posteriorly, but not forward as in the more common Wilm's tumor, a normal pyelogram and a tumor of the upper right abdomen more easily palpable anteriorly than in the flank should suggest the possibility of a primary liver tumor in an infant. Hamartoma cannot be distinguished from adenoma without exploration.

The technic of resection of the liver is fairly well-standardized.[7, 9, 11] Improved anesthesia and restorative therapy now permit resection of liver tumors with increased safety. Fibrin foam or gelatin sponge with thrombin should be useful hemostatic adjuncts. The febrile postoperative course of our patient was not adequately explained but may have been the result of liver trauma.

SUMMARY

Hamartoma of the liver is a structurally variable but benign and resectable tumor of the liver which occurs predominantly in infants. Despite the frequency of malignant liver tumors, surgical exploration is considered justifiable because of the occasional occurrence of hamartoma or other benign tumor, in which case a good prognosis may be given if the tumor is totally removed.

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A CASE OF GLOMUS TUMOR WITH PRIMARY INVOLVEMENT OF BONE

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SINCE PIERRE MASSON, in 1924, published his paper entitled "Le glomus neuro-myo-artériél des régions tactiles et ses tumeurs," the neuromyo-arterial glomus and its tumors have been the subject of numerous and often excellent publications.

Although definitely uncommon, the glomus tumor has now become a well-recognized clinical and pathologic entity. A preoperative diagnosis based on the typical history and symptoms is often possible, and the microscopic characteristics of the neoplasm are now well known to the pathologist. It would, therefore, seem superfluous to report another case were it not for one reason, *i.e.*, its location which, as far as we are aware, has been reported only once before in the literature.

Case Report.—*Clinical History:* The patient is a 28-year-old white woman who came to the hospital with the chief complaint of pain in the right thumb of about four years duration. The past history is noncontributory except that about ten years ago her right hand was caught in the door of a train injuring the thumb. She, however, does not remember that at that time any ecchymosis or incapacitating wound resulted.

The symptoms developed gradually and consisted of a sharp and stabbing pain recurring at irregular intervals and not relieved by aspirin or warm water soaks. Apparently with the pain there always were associated small deep vesicles of the skin of the distal phalanx of the same thumb.

Physical Examination: Blood pressure 108/76. The thumb nail appeared enlarged and curved in all directions. The finger was slightly enlarged and the skin somewhat thickened and discolored. These areas of red discoloration were painless to the touch. On the volar surface there was an area of paler skin in which lay many deep vesicles filled with clear fluid. There was cyanosis of the nail bed and the whole finger was warmer than the others. The skin of the finger was sensitive to the touch. The superficial radial vein of the thumb appeared enlarged.

Roentgenograms (Fig. 1) showed honey-combed areas of decalcification of the distal phalanx suggesting cysts or an enchondroma.

On the basis of these findings, the clinical diagnosis varied as follows: (A) Passive congestion possibly caused by cervical rib (disproved roentgenologically). (B) Chondroma. (C) Bone cyst. (D) Glomus tumor.

On December 15, 1944, the patient was operated upon by one of us (D.B.) under avertin-gas-oxygen anesthesia. No soft-tissue masses were found. The terminal phalanx of the thumb was found to be almost completely replaced by areas of softening containing a jelly-like material. Only a paper thin cortex was left. The lesion was curetted and the defect was filled with a bone graft. The patient, seen recently, more than one year after the operation, appears to be completely cured of the symptoms caused by the intraphalangeal tumor. Roentgenograms demonstrate the bone graft to have maintained the full length of the phalanx if not quite the entire diameter.

Pathologic Examination.—Gross: (S. P. 91809): This consisted of a few small, irregularly-shaped fragments of jelly-like pale tissue, the largest of which measured about 6 mm. in average dimensions. A few small spicules of bone were also present.

Microscopic Examination (Figs. 2 and 3): Sections show a neoplasm, the main characteristic of which consists of the presence of "epithelioid" cells arranged in perivascular cuffs around numerous endothelium-lined spaces. The tumor cells are polygonal and, in general, closely apposed and contain round nuclei with one or more small nucleoli. Around the nuclei sometimes there is a clear halo in the cytoplasm. Besides the above described perivascular arrangement, the neoplastic elements form also solid masses and cords. These are separated by a loose, poorly cellular, myxomatous tissue in which are often found elongated, spindle-shaped elements resembling smooth muscle cells. However, myofibrils cannot be made out with certainty in these cells. Well preserved bone lamellae are seen here and there in the neoplastic tissue (Fig. 2). A

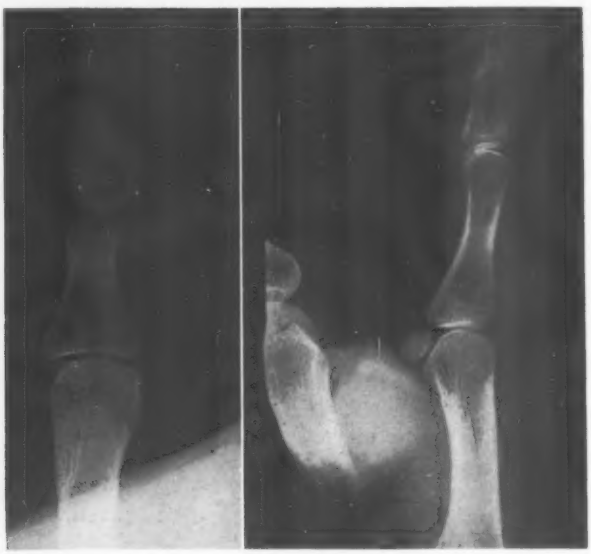

FIG. 1.—The bone of the terminal phalanx shows multiple cyst-like areas of decalcification.

Laidlaw stain for reticulin shows the presence of delicate argentaffine fibers between the tumor cells. Furthermore, it shows that in the perivascular cuffs the tumor cells are all arranged outside the reticulin membrane of the vessels, thus, ruling out a possible endothelial origin of the neoplasm.

The histologic features are typical of a glomus tumor. The presence of spindle-shaped glomus cells that appear to represent a transition between the typical epithelioid elements and smooth muscle cells finds its counterpart in the normal neuromyo-arterial glomus in which there is a gradual transition from the smooth muscle cells of the afferent arteriole to the glomus cells surrounding the "Suquet-Hoyer canal," and then again to the smooth muscle of the efferent vein.

As already mentioned, this case was considered worthy of publication because of its unusual location within the bone of the terminal phalanx.

In the collection of the Laboratory of Surgical Pathology of the College

of Physicians and Surgeons, there are now 44 recorded cases of glomus tumors distributed as follows:*

Fingers: 22, of which 11 are subungual.
Toes: 2, both subungual.
Forearm and arm: 8.
Lower extremity (thigh and leg): 10, of which 1 is in the capsule of the knee joint, and another one in the malleolar region showing features of malignancy.
Gluteal region: 1.
Lower eyelid: 1.

FIG. 2.—Low power photomicrograph showing the close relationship between a lamella of bone and the neoplastic tissue.

Only one other report of a glomic tumor completely encased in the bone of a phalanx could be found in the medical literature. This was published in Cuba by Iglesias de La Torre, Gomez-Camajo, and Palacios. The patient was a 32-year-old woman who had been complaining of severe pain of four years duration affecting the whole upper left extremity but subject to paroxysmal exacerbations following the slightest trauma to the tip of the left ring finger. The inspection of this finger did not reveal anything noteworthy, but there was an exquisite tenderness of the last phalanx. The fingernail and the nail bed were apparently normal. Roentgenograms showed a small cystic cavity 0.5 cm. in diameter. The patient was completely cured following disarticulation of the last phalanx, and the intraphalangeal cavity was found to contain a typical glomus tumor.

This is, therefore, probably the second case report of a glomus tumor completely encased in bone. Other well-documented cases can be found in the literature of glomus tumors arising away from the cutaneous-subcutaneous junction, where normal glomera are exclusively found, according to the studies of Masson.

The occurrence of such cases can be explained in two possible ways: (A)

* It might be interesting to note that this group of glomic tumors shows an absolute predominance of females for the tumors arising in fingers and toes (21 out of 25), and of males for those tumors distributed in the other regions of the body (18 out of 24). Another noteworthy feature is that only one of the cases of this series behaved in a malignant fashion.

By speculating on the existence of normal neuromyo-arterial glomera anywhere in the body, but so sparsely distributed as to make it practically impossible to find them on routine histologic examination. This is pure speculation, as it is not supported by any positive data. (B) By considering the glomus tumor as an hemangiopericytoma of a highly differentiated and specialized variety.

The problem of the distribution of the glomic tumors, and of the significance of their occurrence in regions in which no normal glomera are found

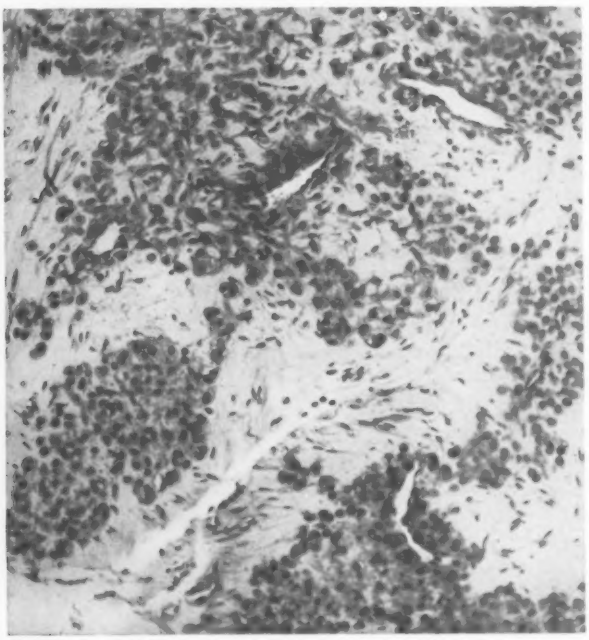

FIG. 3.—High power photomicrograph showing the typical structure of the glomus tumor.

has been the object of very interesting studies published in 1942 by Murray and Stout. These authors, studying explants of a glomus tumor by the method of tissue culture, concluded that there are no fundamental differences between the "epithelioid" cell of the glomus and "pericyte" of Zimmermann. This cell, which Zimmermann considered a modified smooth muscle cell, was found by him around blood capillaries. Possibly it is identical with the contractile adventitial cells described by Rouget, and others.

Murray and Stout felt that the identification of the glomus cell as the pericyte of Zimmermann offered a satisfactory explanation for the occurrence of glomic tumors away from the regions where normal glomera are found.

One might argue that the glomus tumor consists of a complex growth of an organoid character due to the presence, in addition and in close association with the epithelioid "pericytes," of large numbers of nerve fibers and fre-

quently of smooth muscle cells. On the other hand, the hemangiopericytoma as described by Stout and Murray is relatively a simpler growth which is the result of a neoplastic proliferation of poorly differentiated perivascular elements. However, it is very probable that both the glomus cell and the pericyte represent modified smooth muscle elements from the walls of the blood vessels. Most likely they both descend from a common undifferentiated stem cell, and it is, therefore, conceivable that a neoplasm arising from such stem cell might differentiate into a glomus tumor even if no normal glomera are normally found in that particular region.

SUMMARY

A case of glomus tumor completely encased in the bone of the terminal phalanx of a finger is presented. Only one other report of a similarly located glomus tumor could be found.

The pathogenesis of glomus tumors arising where no normal glomera have ever been found is briefly discussed.

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SPECIAL NOTICE

U. S. PUBLIC HEALTH SERVICE RESEARCH GRANTS PROGRAM

THE U. S. PUBLIC HEALTH SERVICE RESEARCH GRANTS PROGRAM, which has been in operation since 1946, is financed by public funds in the support of research—conducted without government control—by independent scientists. The purpose of these grants is to stimulate research in medical and allied fields by making funds available and by actively encouraging scientific investigation of specific problems on which scientists agree that urgently needed information is lacking. Since 1946, a total of $11,061,000 has been provided for the program, exclusive of appropriations for research grants in the fields of cancer and mental health. A total of 16 grants, which represents an expenditure of $159,910, has been approved.

Late in 1945 the Research Grants Division was established to administer the grant program of the Public Health Service with Dr. C. J. Van Slyke as Chief. In July 1947, in order to coordinate programs of research grants and research fellowships, the U. S. Public Health Service Fellowship Program was delegated to the Research Grants Division, which is now known as the Division of Research Grants and Fellowships.

Final recommendations to the Surgeon General of the Public Health Service are made by the National Advisory Health Council regarding all research grants except those relating specifically to the fields of cancer and mental health, for which the National Advisory Cancer Council and the National Advisory Mental Health Council are responsible, respectively.

At the request of the National Advisory Health Council the fields of medical and allied research were classified into 20 major categories, and Special Study Sections made up of consultant experts in these 20 fields have been established. Late in 1946 the Surgery Study Section was organized with Dr. Frederick A. Coller, Professor of Surgery, University of Michigan School of Medicine, as Chairman.

The 16 grants which have been activated in the field of surgery cover the following general subjects: Mitral stenosis, hyperactivity of sympathetic efferent nerves, revascularization of the heart, experimental pulmonary stenosis, development of a pump-oxygenator for use in surgery, parasympathetic regulation of gastrointestinal activity, therapy of debilitated surgical patients, systematic metabolic changes following trauma, peritonitis of intestinal origin, biliary pancreatic reflux and diseases of pancreas and biliary tract, restoration of circulation after arterial severance, complications after vagotomy, amino acids and wound healing, etiology of acid-peptic ulcer, and etiology of ulcerative colitis.

There is, of course, great urgency for additional studies in the field of surgery. Specifically, information is needed concerning shock, heart and lung complications, infection, anesthesia, and wound healing. There is reason to believe that the ratio of complications and death may be 10 times higher with some anesthetic agents than with others.

Shortening of the period of disability following operation is a major economic and public health problem.

The development of new surgical procedures is needed for the solution of old problems, such as cancer, heart disease, hypertension, kidney and liver disease, peptic ulcer and tuberculosis.

Research must develop safe methods for reducing the hazard of surgery in the aged.

Applications for grants may be submitted at any time and should be addressed to: Chief, Division of Research Grants and Fellowships, National Institute of Health, Bethesda 14, Maryland.